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NOVEMBER '74-
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FINAL REPORT

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PROTOTYPE OIL SHALE LEASING PROGRAM

OIL SHALE TRACT C-b

ENVIRONMENTAL BASELINE PROGRAM

FINAL REPORT

(November 1974 Through October 1976)

VOLUME IV

ECOLOGY

Submitted to:

Mr. Peter A. Rutledge
Area Oil Shale Supervisor
Conservation Division
U. S. Geological Survey
Grand Junction, Colorado

By:

C-b Shale Oil Venture
Ashland Oil, Inc.
Occidental Oil Shale, Inc., Operator

ROBERT L. ELDERKIN, JR.
ENVIRONMENTAL SCIENTIST (RECLAMATION)

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Section:	
1. Microenvironment	Principle Investigator: Erik R. Olgeirson, Ph.D. Quality Development Associates, Inc. Denver, Colorado
2. Soils	Co-Principle Investigators: Erik R. Olgeirson, Ph.D. Quality Development Associates, Inc. Denver, Colorado and Walter R. Odening, Ph.D. Woodward-Clyde Consultants San Diego, California
3. Vegetation	Principle Investigator: Warren R. Keammerer, Ph.D. Stoecker-Keammerer and Associates Boulder, Colorado

4. Big Game Medium-Sized Mammals	Principle Investigator: Robert E. Stoecker, Ph.D. Stoecker-Keammerer and Associates Boulder, Colorado
Small Mammals Reptiles and Amphibians Arthropods	Principle Investigator: Stephen D. Kellogg Woodward-Clyde Consultants San Diego, California
Birds	Co-Principle Investigators: Stephen G. Martin, Ph.D. and Patricia Kennedy Environmental Research and Technology, Inc. Ecology Consultants, Inc. Fort Collins, Colorado
5. Aquatic Ecology	Principle Investigator: Preston E. Porter Woodward-Clyde Consultants San Diego, California

In-field program management and coordination were performed by:

Joan Gibbs; Quality Development Associates, Inc.; Vegetation, Microenvironment, Aquatic Ecology, Birds, Big Game

José Merino; TOSCO; Small Mammals, Amphibians and Reptiles, Arthropods, Big Game

The task of acquiring and analyzing data was aided by the following contributors:

Nancy Aitkenhead; Woodward-Clyde Consultants; Statistics and Graphic Presentation

Edward Baker; Occidental Shale Oil, Inc.; Vegetation

James Beley; Woodward-Clyde Consultants; Vegetation, Small Mammals

Spencer Bullard; Quality Development Associates, Inc.; Statistical Analysis

William Costello; Woodward-Clyde Consultants; Aquatic Ecology

Steven Dougherty; Quality Development Associates, Inc.; Microenvironment and Soils

Ronald Freeman; Woodward-Clyde Consultants

Michael Glenn; Woodward-Clyde Consultants; Dendroclimatology

Deborah Keammerer; Stoecker-Keammerer and Associates; Vegetation and Habitat Mapping

Karen Larson; Woodward-Clyde Consultants; Vegetation

Barry Mountain; Quality Development Associates, Inc.; Microenvironment Data Reduction and Presentation

Robert Post; Woodward-Clyde Consultants; Aquatic Ecology

Clayton Spears; United States Department of Agriculture, Soil Conservation Service; Soil Description and Mapping

Dennis Van Horn; Environmental Research and Technology, Inc.; Ecology Consultants, Inc.; Birds

James Ward, Ph.D.; Colorado State University; Aquatic Ecology

VOLUME IV ECOLOGY

TABLE OF CONTENTS

Page

Acknowledgments i

Table of Contents v

List of Figures xxix

List of Tables xxxv

Summary 1

- S.1 Microenvironment 3
- S.2 Soils 5
- S.3 Vegetation 7
  - S.3.1 Flora 7
  - S.3.2 Plant Communities 7
    - S.3.2.1 Pinyon-Juniper Woodland 7
    - S.3.2.2 Chained Pinyon-Juniper Rangeland 8
    - S.3.2.3 Big Sagebrush Communities 8
      - S.3.2.3.1 Upland Sagebrush Communities 8
      - S.3.2.3.2 Bottomland Sagebrush Communities 8
    - S.3.2.4 Douglas-fir Forests 9
    - S.3.2.5 Mixed Mountain Shrublands 9
    - S.3.2.6 Bunchgrass Community 9

Page

S.3.2.7 Marshlands 10

S.3.2.8 Riparian Communities 10

S.3.2.9 Great Basin Wild Rye Communities 10

S.3.2.10 Rabbitbrush Communities 10

S.3.2.11 Greasewood Communities 11

S.3.2.12 Agricultural Meadows 11

S.3.2.13 Annual Weed Communities 11

S.3.2.14 Aquatic Plant Communities 11

S.3.3 Intensive Study Plot Studies 11

S.3.3.1 Herb Layer Composition 11

S.3.3.2 Shrub Layer Structure and Composition 12

S.3.3.3 Tree Layer 12

S.3.3.4 Production Studies 12

S.3.3.4.1 Herb Production 12

S.3.3.4.2 Shrub Production 13

S.3.3.5 Decomposition and Litter Studies 13

S.3.3.6 Herb Phenology Studies 13

S.3.3.7 Shrub Stem Growth Studies 13

S.4 Animals 15

S.4.1 Big Game 15

S.4.2 Medium-sized Mammals 15

S.4.3 Small Mammals 15

S.4.4 Birds 18

Page

S.4.4.1 Songbirds 18

S.4.4.2 Upland Gamebirds 19

S.4.4.3 Waterfowl and Shorebirds 20

S.4.4.4 Raptors 20

S.4.5 Amphibians and Reptiles 21

S.4.6 Terrestrial Arthropods 21

S.5 Aquatics 23

1 Introduction 25

2 Program Description 29

2.1 Lease Requirements and Stipulations 29

2.2 Baseline Study 31

2.2.1 Objectives 31

2.2.2 Physical Environment 31

2.2.3 Vegetation 32

2.2.4 Wildlife 32

2.2.5 Aquatic Ecology 32

3 Baseline Programs 35

3.1 Microenvironment 35

3.1.1 Rationale 35

3.1.2 Objectives 36

3.1.3 Experimental Design 37

3.1.3.1 Measurement of Parameters 37

3.1.3.2 Statistical Comparisons of the Four Microenvironmental Stations 37

Page

3.1.3.2.1 Four-Factor Analysis of Variance 40

3.1.3.2.2 Three-Factor Analysis of Variance 40

3.1.3.2.3 Single-Factor Analysis of Variance 41

3.1.3.2.4 The Newman-Keuls Test 41

3.1.4 Methods 42

3.1.4.1 Parameter Measurement and Data Reduction 42

3.1.4.2 Statistical Comparisons of the Four Microenvironmental Stations 42

3.1.5 Results and Discussion 43

3.1.5.1 Microenvironmental Characteristics of Tract C-b 43

3.1.5.1.1 General 43

3.1.5.1.2 Temperature 44

3.1.5.1.3 Moisture 56

3.1.5.1.3.1 Precipitation 56

3.1.5.1.3.2 Soil Moisture 61

3.1.5.2 Statistical Comparisons Between the Four Microenvironmental Stations 67

3.2 Soils 71

3.2.1 Rationale 71

3.2.2 Objectives 71

3.2.3 Experimental Design 72

3.2.3.1 Soil Survey/Mapping 72

3.2.3.2 Soil Nutrients 72

Page

3.2.3.3 Soil Productivity 72

3.2.3.4 Soil-Plant Interrelationship Studies 72

3.2.3.5 Soil Biotic Studies 73

3.2.4 Methods 73

3.2.4.1 Soil Survey/Mapping 73

3.2.4.2 Soil Nutrients 73

3.2.4.3 Soil Productivity 74

3.2.4.4 Soil-Plant Interrelationships 74

3.2.4.4.1 Vegetation 74

3.2.4.4.2 Soils 75

3.2.4.4.3 Statistical Analysis 75

3.2.4.5 Soil Biotic Studies 75

3.2.5 Results and Discussion 75

3.2.5.1 Soil Survey 75

3.2.5.1.1 Classification of Soils 77

3.2.5.1.1.1 Identification of Soil Taxonomic Units 77

3.2.5.1.1.2 Interpretations of Soil Taxonomic Units with Respect to Soil Moisture 77

3.2.5.1.1.3 Interpretations of Soil Taxonomic Units with Respect to Soil Temperature 78

3.2.5.1.1.4 General Description of Soil Taxonomic Units 78

3.2.5.1.1.5 Classification of Soils on the Tract 79

Page

3.2.5.2 Soil Chemical and Physical Analysis 84

3.2.5.3 Soil Productivity 87

3.2.5.4 Soil-Vegetation Interrelationships 93

3.2.5.4.1 Interspecific Competition 96

3.2.5.4.1.1 Analysis of Variance 96

3.2.5.4.1.2 Correlation and Regression Analysis 100

3.2.5.5 Soil Biotic Studies 115

3.2.5.5.1 Soil Fungi 115

3.2.5.5.2 Soil Actinomycetes 118

3.2.5.5.3 Soil Bacteria 118

3.3 Vegetation Studies 121

3.3.1 Rationale for Component Studies 121

3.3.1.1 Flora 121

3.3.1.2 Phytosociological Studies 121

3.3.1.3 Productivity Studies 122

3.3.1.4 Decomposition and Litter Fall Studies 122

3.3.1.5 Herb Phenology 123

3.3.1.6 Shrub Stem Growth Studies 123

3.3.2 Objectives of Component Studies 123

3.3.2.1 Flora 123

3.3.2.2 Phytosociological Studies 123

3.3.2.3 Vegetation Mapping 123

3.3.2.4 Broadly Based Vegetation Sampling Program 124

3.3.2.5 Intensive Study Plot Studies 124

Page

3.3.2.6 Productivity Studies 124

3.3.2.7 Decomposition and Litter Fall Studies 124

3.3.2.8 Herb Phenology 125

3.3.2.9 Shrub Stem Growth Studies 125

3.3.3 Experimental Design 125

3.3.3.1 Phytosociological Studies 125

3.3.3.1.1 Broadly Based Sampling Program 125

3.3.3.1.2 Intensive Study Plots 127

3.3.3.2 Productivity Studies 129

3.3.3.2.1 Herb Production Studies 129

3.3.3.2.2 Shrub Production Studies 130

3.3.3.2.3 Current Year's Growth for Antelope Bitterbrush and Mountain Mahogany 130

3.3.3.3 Decomposition and Litter Studies 132

3.3.3.3.1 Decomposition Studies 132

3.3.3.3.2 Litter Fall Studies 132

3.3.3.4 Herb Phenology 134

3.3.3.5 Shrub Stem Growth Studies 134

3.3.4 Brief Methodological Descriptions 134

3.3.4.1 Flora 134

3.3.4.2 Phytosociological Studies 136

3.3.4.2.1 Vegetation Mapping 136

3.3.4.2.2 Broadly Based Vegetation Sampling Program 136

3.3.4.2.3 Intensive Study Plot Studies 136

Page

3.3.4.3 Productivity Studies 136

3.3.4.3.1 Herb Production Studies 136

3.3.4.3.2 Shrub Production Studies 136

3.3.4.4 Decomposition and Litter Fall Studies 138

3.3.4.5 Herb Phenology 138

3.3.4.6 Shrub Stem Growth Studies 138

3.3.5 Results and Discussion 138

3.3.5.1 Flora 138

3.3.5.2 Description of Plant Communities 139

3.3.5.2.1 Pinyon-Juniper Woodlands 140

3.3.5.2.1.1 General Location and Distribution 140

3.3.5.2.1.2 Structure and Composition 140

3.3.5.2.1.3 Stability, Diversity, and Succession 141

3.3.5.2.1.4 Environment 141

3.3.5.2.1.5 Current Land Use and Management 143

3.3.5.2.2 Chained Pinyon-Juniper Rangeland 143

3.3.5.2.2.1 General Location and Distribution 143

3.3.5.2.2.2 Structure and Composition 144

3.3.5.2.2.3 Stability, Diversity, and Succession 144

3.3.5.2.2.4 Environment 146

3.3.5.2.2.5 Current Land Use and Management 146

Page

3.3.5.2.3 Big Sagebrush Communities 146

3.3.5.2.3.1 Upland Sagebrush Communities 147

3.3.5.2.3.2 Bottomland Sagebrush Communities 150

3.3.5.2.4 Douglas-fir Forests 153

3.3.5.2.4.1 General Location and Distribution 153

3.3.5.2.4.2 Structure and Composition 154

3.3.5.2.4.3 Stability, Diversity, and Succession 154

3.3.5.2.4.4 Environment 155

3.3.5.2.4.5 Current Land Use and Management 155

3.3.5.2.5 Mixed Mountain Shrublands 155

3.3.5.2.5.1 General Location and Distribution 155

3.3.5.2.5.2 Structure and Composition 156

3.3.5.2.5.3 Stability, Diversity, and Succession 157

3.3.5.2.5.4 Environment 157

3.3.5.2.5.5 Current Land Use and Management 157

3.3.5.2.6 Bunchgrass Community 158

3.3.5.2.6.1 General Location and Distribution 158

3.3.5.2.6.2 Structure and Composition 158

3.3.5.2.6.3 Stability, Diversity, and Succession 158

Page

3.3.5.2.6.4 Environment 159

3.3.5.2.6.5 Current Land Use and Management 159

3.3.5.2.7 Marshlands 159

3.3.5.2.7.1 General Locations and Distribution 159

3.3.5.2.7.2 Structure and Composition 160

3.3.5.2.7.3 Stability, Diversity, and Succession 160

3.3.5.2.7.4 Environment 160

3.3.5.2.7.5 Current Land Use and Management 160

3.3.5.2.8 Riparian Communities 161

3.3.5.2.8.1 General Location and Distribution 161

3.3.5.2.8.2 Structure and Composition 161

3.3.5.2.8.3 Stability, Diversity, and Succession 161

3.3.5.2.8.4 Environment 161

3.3.5.2.8.5 Current Land Use and Management 162

3.3.5.2.9 Great Basin Wild Rye Communities 162

3.3.5.2.9.1 General Location and Distribution 162

3.3.5.2.9.2 Structure and Composition 162

3.3.5.2.9.3 Stability, Diversity, and Succession 163

3.3.5.2.9.4 Environment 163

Page

3.3.5.2.9.5 Current Land Use and Management 163

3.3.5.2.10 Rabbitbrush Communities 163

3.3.5.2.10.1 General Location and Distribution 163

3.3.5.2.10.2 Structure and Composition 164

3.3.5.2.10.3 Stability, Diversity, and Succession 164

3.3.5.2.10.4 Environment 164

3.3.5.2.10.5 Current Land Use and Management 165

3.3.5.2.11 Greasewood Communities 165

3.3.5.2.11.1 General Location and Distribution 165

3.3.5.2.11.2 Structure and Composition 165

3.3.5.2.11.3 Stability, Diversity, and Succession 166

3.3.5.2.11.4 Environment 166

3.3.5.2.11.5 Current Land Use and Management 167

3.3.5.2.12 Agricultural Meadows 167

3.3.5.2.13 Annual Weed Communities 168

3.3.5.2.13.1 General Location and Distribution 168

3.3.5.2.13.2 Structure and Composition 168

3.3.5.2.13.3 Stability, Diversity, and Succession 168

3.3.5.2.13.4 Environment 169

3.3.5.2.13.5 Current Land Use and Management 169

Page

3.3.5.2.14 Aquatic Plant Communities 169

3.3.5.2.14.1 Lentic 169

3.3.5.2.14.2 Lotic 169

3.3.5.3 Similarities Among Vegetation Types 169

3.3.5.4 Intensive Study Plot Studies 176

3.3.5.4.1 Herb Layer Composition 176

3.3.5.4.2 Shrub Layer Structure and Composition 178

3.3.5.4.2.1 Frequency 178

3.3.5.4.2.2 Cover Values and Percent Composition 179

3.3.5.4.2.3 Density 179

3.3.5.4.3 Tree Layer 180

3.3.5.5 Production Studies 181

3.3.5.5.1 Herb Production Studies 181

3.3.5.5.1.1 Chained Rangelands 181

3.3.5.5.1.2 Pinyon-Juniper Woodlands 184

3.3.5.5.1.3 Upland Sagebrush 186

3.3.5.5.1.4 Bottomland Sagebrush 187

3.3.5.5.1.5 Differences Among Vegetation Types 187

3.3.5.5.1.6 Evaluation of Fencing Effects 188

3.3.5.5.1.7 Herb Production Differences Between 1975 and 1976 190

3.3.5.5.2 Shrub Production 194

Page

3.3.5.5.2.1 Bottomland Sagebrush Communities 194

3.3.5.5.2.2 Upland Sagebrush Communities 194

3.3.5.5.2.3 Chained Rangelands 199

3.3.5.5.2.4 Pinyon-Juniper Woodlands 199

3.3.5.5.2.5 Comparison Between 1975 and 1976 199

3.3.5.5.2.6 Current Year's Growth Studies 200

3.3.5.6 Decomposition and Litter Studies 203

3.3.5.6.1 Decomposition Studies 203

3.3.5.6.1.1 Sample Depth Comparisons 207

3.3.5.6.1.2 Time Comparisons 207

3.3.5.6.1.3 Test Material Comparisons 208

3.3.5.6.1.4 Site Comparisons 208

3.3.5.6.2 Litter Fall Studies 209

3.3.5.7 Herb Phenology Studies 211

3.3.5.8 Shrub Stem Growth Studies 212

3.3.5.8.1 _Amelanchier_ spp. 212

3.3.5.8.2 _Cercocarpus montanus_ 213

3.3.5.8.3 _Artemisia tridentata_ 214

3.4 Animals 217

3.4.1 Big Game 217

3.4.1.1 Rationale 217

3.4.1.1.1 Mule Deer Movement 217

3.4.1.1.2 Mule Deer Habitat Utilization 217

3.4.1.1.3 Mule Deer Mortality Studies 218

3.4.1.2 Objectives 218

3.4.1.2.1 Mule Deer Movement Patterns 218

3.4.1.2.2 Mule Deer Habitat Utilization 218

3.4.1.2.3 Mule Deer Mortality Studies 218

3.4.1.3 Experimental Design 219

3.4.1.3.1 Mule Deer Movement Patterns 219

3.4.1.3.2 Mule Deer Habitat Utilization 219

3.4.1.3.3 Mule Deer Mortality Studies 219

3.4.1.4 Brief Methodological Description 219

3.4.1.4.1 Mule Deer Movement Patterns 219

3.4.1.4.2 Mule Deer Habitat Utilization 220

3.4.1.4.2.1 Pellet-group Counts 220

3.4.1.4.2.2 Browse Production and Utilization by Shoot Measurements 221

3.4.1.4.2.3 Browse Condition Using Ocular Methods 221

3.4.1.4.3 Mule Deer Mortality Studies 222

3.4.1.5 Results and Discussion 222

3.4.1.5.1 Mule Deer Movement Patterns 222

Page

3.4.1.5.2 Mule Deer Habitat Utilization 231

3.4.1.5.3 Mule Deer Mortality Studies 233

3.4.1.5.4 Elk 239

3.4.2 Medium-sized Mammals 239

3.4.2.1 Rationale 239

3.4.2.2 Objectives 239

3.4.2.3 Experimental Design 239

3.4.2.4 Methods 240

3.4.2.5 Results and Discussion 240

3.4.3 Small Mammals 246

3.4.3.1 Rationale 246

3.4.3.2 Objectives 247

3.4.3.3 Experimental Design 247

3.4.3.4 Brief Methodological Description 249

3.4.3.5 Results and Discussion 251

3.4.3.5.1 Species Composition and Summary of Local Distribution of Small Mammals on Tract C-b 251

3.4.3.5.1.1 Deer Mouse (_Peromyscus maniculatus_) 253

3.4.3.5.1.2 Least Chipmunk (_Eutamias minimus_) 254

3.4.3.5.1.3 Uinta Chipmunk (_Eutamias umbrinus_) 254

3.4.3.5.1.4 Montane Vole (_Microtus montanus_) 254

Page

3.4.3.5.1.5 Golden Mantled Ground Squirrel (_Spermophilus lateralis_) 254

3.4.3.5.1.6 Apache Pocket Mouse (_Perognathus apache_) 255

3.4.3.5.1.7 Bushy-Tailed Woodrat (_Neotoma cinerea_) 255

3.4.3.5.2 Density Estimates and Trap Success on Quantitative Grids and Satellite Grids 255

3.4.3.5.2.1 Seasonal and Annual Fluctuations 255

3.4.3.5.2.2 Comparison of Small Mammal Populations on Grids 1 and 2 268

3.4.3.5.3 Reproduction 270

3.4.3.5.3.1 Deer Mouse 270

3.4.3.5.3.2 Least Chipmunk 275

3.4.3.5.3.3 Montane Vole 276

3.4.3.5.3.4 Uinta Chipmunk 277

3.4.3.5.4 Live Weights 277

3.4.3.5.4.1 Deer Mouse 277

3.4.3.5.4.2 Least Chipmunk and Uinta Chipmunk 277

3.4.3.5.5 Home Ranges 281

3.4.3.5.6 Survivorship and Turnover Rate of Marked Animals on Grids 1 and 2 283

3.4.3.5.6.1 Deer Mouse 286

3.4.3.5.6.2 Least Chipmunk 286

3.4.3.5.6.3 Uinta Chipmunk 287

Page

3.4.3.5.7 Food Habits 287

3.4.3.5.7.1 Deer Mouse 287

3.4.3.5.7.2 Least Chipmunk 289

3.4.4 Birds 289

3.4.4.1 Rationale 289

3.4.4.1.1 Census Measures 289

3.4.4.1.2 Habitat Requirements of Principal Species 289

3.4.4.2 Objectives 290

3.4.4.2.1 Census Measures 290

3.4.4.2.2 Habitat Requirements of Principal Species 290

3.4.4.3 Experimental Design 290

3.4.4.3.1 Experimental Design-Census Measures 291

3.4.4.3.1.1 Quantitative Songbird Censuses 291

3.4.4.3.1.2 Qualitative Songbird Censuses 295

3.4.4.3.1.3 Upland Gamebirds 295

3.4.4.3.1.4 Waterfowl and Shorebirds 295

3.4.4.3.1.5 Raptors 295

3.4.4.4 Brief Methodological Description 296

3.4.4.4.1 Census Measures 296

3.4.4.4.1.1 Quantitative Songbird Censuses 296

3.4.4.4.1.2 Qualitative Songbird Census 297

Page

3.4.4.4.1.3 Upland Gamebirds 297

3.4.4.4.1.4 Waterfowl and Shorebirds 298

3.4.4.4.1.5 Raptors 298

3.4.4.4.2 Habitat Requirements for Principal Species 298

3.4.4.5 Results and Discussion 300

3.4.4.5.1 Data Summary 300

3.4.4.5.2 Songbirds 302

3.4.4.5.2.1 Interpretive Summary of Census Results 302

3.4.4.5.3 Upland Gamebird Observations 322

3.4.4.5.4 Waterfowl 323

3.4.4.5.5 Raptors 328

3.4.4.5.6 Habitat Requirements of Principal Species 339

3.4.5 Amphibians and Reptiles 340

3.4.5.1 Rationale 340

3.4.5.2 Objectives 340

3.4.5.3 Experimental Design 340

3.4.5.4 Brief Methodological Description 343

3.4.5.5 Results and Discussion 343

3.4.5.5.1 Species Composition 343

3.4.5.5.2 Relative Abundance of Reptiles on Small Mammal Grids 1 and 2 343

3.4.5.5.3 Turnover and Longevity 345

3.4.5.5.4 Food Habits 346

Page

3.4.6 Terrestrial Invertebrates 346

3.4.6.1 Rationale 346

3.4.6.2 Objectives 346

3.4.6.3 Experimental Design 347

3.4.6.4 Brief Methodological Description 347

3.4.6.5 Results and Discussion 347

3.4.6.5.1 Ground Dwelling Arthropods 347

3.4.6.5.1.1 Species Composition and Relative Abundance 347

3.4.6.5.1.2 Trophic Structure Analysis 348

3.4.6.5.2 Shrub Dwelling Arthropods 352

3.4.6.5.2.1 Species Composition and Species Diversity 352

3.4.6.5.2.2 Relative Abundance and Trophic Structure Analysis 354

3.5 Aquatic Ecology 361

3.5.1 Rationale 361

3.5.1.1 Water Quality and Sediments 361

3.5.1.2 Plankton 362

3.5.1.3 Periphyton 362

3.5.1.4 Benthos 362

3.5.1.5 Fish 362

3.5.1.6 Springs and Seeps 363

3.5.2 Objectives 363

3.5.2.1 Water Quality and Sediments 363

3.5.2.2 Plankton 363

Page

3.5.2.3 Periphyton 363

3.5.2.4 Benthos 363

3.5.2.5 Fish 364

3.5.2.6 Springs and Seeps 364

3.5.3 Experimental Design 364

3.5.3.1 Water Quality and Sediments 364

3.5.3.2 Plankton 365

3.5.3.3 Periphyton 365

3.5.3.4 Benthos 365

3.5.3.5 Fish 365

3.5.3.6 Springs and Seeps 365

3.5.4 Brief Methodological Description 365

3.5.4.1 Water Quality and Sediments 366

3.5.4.2 Plankton 366

3.5.4.3 Periphyton 366

3.5.4.4 Benthos 366

3.5.4.5 Fish 366

3.5.4.6 Springs and Seeps 366

3.5.5 Results and Discussions 367

3.5.5.1 Water Quality and Sediments 367

3.5.5.1.1 Temperature 367

3.5.5.1.2 pH 367

3.5.5.1.3 Dissolved Oxygen 373

3.5.5.1.4 Specific Conductivity 374

3.5.5.1.5 Cations 374

Page

3.5.5.1.5.1 Calcium 374

3.5.5.1.5.2 Magnesium 375

3.5.5.1.5.3 Sodium 375

3.5.5.1.5.4 Potassium 376

3.5.5.1.5.5 Ammonia 376

3.5.5.1.6 Anions 377

3.5.5.1.6.1 Hydroxide 377

3.5.5.1.6.2 Carbonate 377

3.5.5.1.6.3 Bicarbonates 377

3.5.5.1.6.4 Sulfate 378

3.5.5.1.6.5 Chloride 378

3.5.5.1.6.6 Nitrate 379

3.5.5.1.7 Organics 379

3.5.5.1.7.1 Ortho-phosphates 379

3.5.5.1.7.2 Ammonia (N) 380

3.5.5.1.8 Inorganics 380

3.5.5.1.8.1 Boron 380

3.5.5.1.8.2 Silica 381

3.5.5.1.8.3 Iron 381

3.5.5.1.8.4 Manganese 382

3.5.5.1.8.5 Nitrate (N) 383

3.5.5.1.8.6 Nitrite (N) 383

3.5.5.1.8.7 Alkalinity ($CaCO_3$) 383

3.5.5.1.8.8 Hardness ($CaCO_3$) 384

3.5.5.1.9 Dissolved Solids 384

Page

3.5.5.1.10 Microbiology 385

3.5.5.1.10.1 Coliform Bacteria 385

3.5.5.1.10.2 Fecal Streptococci 390

3.5.5.1.10.3 Pathogens 390

3.5.5.2 Plankton 392

3.5.5.3 Periphyton 394

3.5.5.4 Benthos 396

3.5.5.5 Fish Populations 411

3.5.5.5.1 Mountain Sucker 412

3.5.5.5.2 Speckled Dace 414

3.5.5.5.3 Brook Trout 418

3.5.5.5.4 Other Fish Species 424

3.5.5.6 Springs and Seeps 425

3.5.5.7 Other Studies 425

3.6 Threatened, Endangered, and Unusual Species 427

4 Utilization 429

4.1 Microenvironment 431

4.2 Soils 433

4.3 Vegetation 435

4.3.1 Flora 435

4.3.2 Phytosociological Studies 435

4.3.2.1 Vegetation Mapping 435

4.3.2.2 Broadly Based Sampling Program 435

4.3.2.3 Intensive Study Plots 436

Page

4.3.3 Production Studies 436

4.3.4 Decomposition Studies 437

4.3.5 Herb Phenology Studies 437

4.3.6 Shrub Growth Studies 437

4.4 Animals 439

4.4.1 Big Game 439

4.4.1.1 Mule Deer Movement Patterns 439

4.4.1.2 Mule Deer Habitat Utilization 440

4.4.1.3 Mule Deer Mortality Studies 440

4.4.2 Medium-sized Mammals 440

4.4.3 Small Mammals 440

4.4.3.1 Species Composition and Density Estimates 441

4.4.3.2 Home Range Size 441

4.4.3.3 Small Mammal Reproductive Condition 442

4.4.3.4 Small Mammal Live Weights 442

4.4.3.5 Small Mammal Survivorship and Turnover Rates 443

4.4.3.6 Small Mammal Food Habit Studies 443

4.4.4 Birds 443

4.4.5 Reptiles and Amphibians 445

4.4.6 Arthropods 445

4.4.6.1 Shrub Dwelling Arthropods 445

4.4.6.2 Ground Dwelling Arthropods 445

4.5 Aquatics 447

4.5.1 Water Quality 447

Page

4.5.2 Periphyton 447

4.5.3 Benthos 448

4.5.4 Fish 448

4.5.5 Springs and Seeps 449

5 References Cited 451

5.1 Microenvironment 451

5.2 Soils 453

5.3 Vegetation 455

5.4 Animals 457

5.5 Aquatics 467

Appendix A Methodology, Experimental Design, and Quality Assurance 473

Appendix B Data Presentation 475

VOLUME IV ECOLOGY

LIST OF FIGURES

Figure Number	Figure	Page
Chapter 3:		
Section 3.1 Microenvironment:		
3-1-1	Locations of Microenvironmental Stations	39
3-1-2	Temperature Summary Pinyon-Juniper Woodland (PJWD), 1975 and 1976, Tract C-b	45
3-1-3	Temperature Summary Chained Pinyon-Juniper Rangeland (CPJR), 1975 and 1976, Tract C-b	46
3-1-4	Temperature Summary Upland Sagebrush (UPSB), 1975 and 1976, Tract C-b	47
3-1-5	Temperature Summary Bottomland Sagebrush (BLSB), 1975 and 1976, Tract C-b	48
3-1-6	Minimum and Maximum Temperature Ranges from Surface and Free Air Sensors, 1975	49
3-1-7	Minimum and Maximum Temperature Ranges from Surface and Free Air Sensors of 1976	50
3-1-8	Monthly Soil Moisture Per Vegetation Type Plotted Against Mean Monthly Precipitation for the Four Major Vegetation Types	55
3-1-9	Precipitation Summary for Four Major Vegetation Types, 1975 and 1976, Tract C-b	57
3-1-10	Comparison of Water Content of Snow and Snow Depth in Four Vegetation Types in Winters of 1974-75 and 1975-76	58
3-1-11	Comparison of Precipitation in 1975 and 1976 for the Four Major Vegetation Types, Tract C-b	60

Figure Number Figure Page

3-1-12 Soil Moisture Curves for the Four Major Vegetation Types, Tract C-b 62

3-1-13 Potential Evaporation Averages of Vegetation Types in Comparison of Two Seasons 65

3-1-14 Mean Wind Speed in the Four Major Vegetation Types, 1975-1976, Tract C-b 68

Section 3.2 Soils:

3-2-1 Soils Map, Tract C-b Pocket

3-2-2 Soil Sample Location Map 86

3-2-3 Growth of *Hordeum vulgare* var. *Briggs* 89

3-2-4 Growth of *Avena sativa* var. *Victory* 90

3-2-5 Soil Productivity Sample Sites 91

3-2-6 Soil Nutrient Summary for the Four Major Vegetation Types in the Tract C-b Study Area 95

3-2-7 Comparison of Importance Value for Seven Important Shrub Species in Five Stand Types in the Tract C-b Study Area 105

3-2-8 Comparison of Frequency Value for Ten Herbaceous Species in Five Stand Types in the Tract C-b Study Area 108

Section 3.3 Vegetation:

3-3-1 Vegetation Sampling Sites 128

3-3-2 The Vegetation of Oil Shale Tract C-b Pocket

Section 3.4 Animals:

3-4-1 Relative Numbers of Deer Tracks on the Major Ridges During Fall and Spring Migrations. All Sampling Locations Occurred in Pinyon-Juniper Woodland at Approximately 7000 ft. (2133 m) Elevation 224

Figure Number	Figure	Page
3-4-2	Summary of Deer Road Counts for First Year of Baseline Study. Heights of Bars are Means; Sample Sizes (N) are the Number of Road Counts for the Period	225
3-4-3	Summary of Deer Road Counts for Second Year of Baseline Study	226
3-4-4	Deer Road Counts in the Willow Creek Meadow Near Tract C-b. The Downward Trend Marks the Beginning of the Spring Deer Migration of 1976	227
3-4-5	Feeding Activities of Deer Observed During Evening Road Counts. Total Number of Deer Observed is Shown Above Hatched Bars. Data are Grouped for Two-Week Intervals	229
3-4-6	Deer Distributions During Mid and Late Winter. Observations Were Made from Fixed-Wing Aircraft After Fresh Snowfalls	230
3-4-7	Trends of Cottontail Abundance on Tract C-b During Two Years of Baseline Study	244
3-4-8	Small Mammal Trapping Sites	248
3-4-9	Small Mammal Grid Design on Grids 1 and 2	250
3-4-10	Percentage of Reproductively Active Peromyscus maniculatus, Eutamias minimus, and Microtus montanus on Grid 1 (Chained Pinyon-Juniper Rangeland)	272
3-4-11	Percentage of Reproductively Active Peromyscus maniculatus, Eutamias minimus, and Eutamias umbrinus on Grid 2 (Pinyon-Juniper Woodland)	273
3-4-12	Persistence (Survivorship) of Marked Animals on Grids 1 and 2	284
3-4-13	Location of Bird Strip Transect Locations and Night Owl Survey Route on Tract C-b and Environs	Pocket
3-4-14	Changes in Total Bird Densities in Four Principal Habitats Over the Two Years of Study	303
3-4-15	Species Diversity Changes in Four Principle Habitats Over the Two Years of Study	304

Figure Number	Figure	Page
3-4-16	Relative Abundance of Arthropods Collected From Pitfalls Located on Grids 1 and 2	349
3-4-17	Species Diversity of Arthropods Collected From Pitfalls Located on Grids 1 and 2	350
3-4-18	Relative Abundance of Arthropods Representing Four Major Trophic Levels Collected From Pitfalls Located on Grids 1 and 2	351
3-4-19	Species Diversity of Arthropods Collected From Three Major Shrub Species on Grids 1 and 2	353
3-4-20	Relative Abundance of Arthropods Collected From Three Major Shrub Species on Grid 1 (Chained Pinyon-Juniper Rangeland)	355
3-4-21	Relative Abundance of Arthropods Collected From Three Major Shrub Species on Grid 2 (Pinyon-Juniper Woodland)	356
3-4-22	Relative Abundance of Arthropods Representing Three Major Trophic Levels Collected From *Cercocarpus montanus* on Grids 1 and 2	357
3-4-23	Relative Abundance of Arthropods Representing Three Major Trophic Levels Collected From *Amelanchier* spp. on Grids 1 and 2	358
3-4-24	Relative Abundance of Arthropods Representing Two Major Trophic Levels Collected From *Artemisia tridentata* on Grids 1 and 2	359

Section 3.5 Aquatic Ecology:

3-5-1	Aquatic Sampling Stations	Pocket
3-5-2	Temperature and Dissolved Oxygen at the Piceance Creek Stations August 1974 - July 1976	369
3-5-3	Temperature and Dissolved Oxygen at the White River Stations August 1974 - July 1976	370
3-5-4	Temperature and Dissolved Oxygen at the Willow Creek Stations August 1974 - July 1976	371

Figure Number	Figure	Page
3-5-5	Temperature and Dissolved Oxygen at the Stewart Creek Stations August 1974 - July 1976	372
3-5-6	Total Dissolved Solids at the Piceance Creek Stations August 1974 to July 1976	386
3-5-7	Total Dissolved Solids at the Stewart Creek Stations August 1974 to July 1976	387
3-5-8	Total Dissolved Solids at the White River Stations August 1974 to July 1976	388
3-5-9	Total Dissolved Solids at the Willow Creek Stations August 1974 to July 1976	389
3-5-10	Benthic Invertebrate Numbers[1] and Biomass[2] for Piceance Creek Stations September 1974 to July 1976	397
3-5-11	Benthic Invertebrate Numbers[1] and Biomass[2] for Stewart Creek and Lakes September 1974 to July 1976	401
3-5-12	Benthic Invertebrate Numbers[1] and Biomass[2] for Willow Creek and Lakes September 1974 to July 1976	403
3-5-13	Benthic Invertebrate Numbers[1] and Biomass[2] for White River September 1974 to July 1976	406
3-5-14	Length-Weight Linear Regression for Mountain Suckers from Piceance Basin (two growth stanzas computed) September 1974 to November 1975	415
3-5-15	Length-Weight Linear Regression for Mountain Suckers from Piceance Basin (two growth stanzas computed) November 1975 - July 1976	416
3-5-16	Mountain Sucker Growth Rates Determined from Fish Aged by Scale Readings Using Average Length (A) and Weight (B)	417
3-5-17	Length-Weight Linear Regression for Brook Trout from Piceance Basin (two growth stanzas computed) September 1974 to November 1975	421

Figure Number	Figure	Page
3-5-18	Length-Weight Linear Regression for Brook Trout from Piceance Basin (two growth stanzas computed) November 1975 to July 1976	422
3-5-19	Brook Trout Growth Rates Determined from Fish Aged by Scale Readings Using Average Length (A) and Weight (B)	423

VOLUME IV ECOLOGY

LIST OF TABLES

Chapter 3:

Section 3.1 Microenvironment:

Table Number	Table	Page
3-1-1	Microenvironmental Instrumentation	38
3-1-2	Occurrence of Frosts in the Four Major Vegetation Types, 1975 - 1976 Tract C-b	52
3-1-3	Growing Season Temperature Maxima and Minima, 1975-76 (^{0}C)	54
3-1-4	Precipitation (mm) Totals (Dec-Sept) for the Four Major Vegetation Types, 1975-76, Tract C-b	59
3-1-5	Soil Moisture and Soil Water Tension for Major Vegetation Types, 1975-76 Tract C-b	64
3-1-6	Available Water Capacity in the Four Major Vegetation Types Tract C-b	66
3-1-7	Potential Evaporation* in the Four Major Vegetation Types Tract C-b	69

Section 3.2 Soils:

Table Number	Table	Page
3-2-1	Soils of Tract Study Area (USDA Soil Classification System, 1960)	76
3-2-2	Soils and Vegetation Associations of the Tract C-b Study Area	80
3-2-3	Summary of Soil Physical and Chemical Characteristics	85

Table Number	Table	Page
3-2-4	Germination Rate Comparison for Soil Productivity Test Samples*	88
3-2-5	Multiple Comparisons Test (Student-Newman-Keuls) for Differences in Shoot Lengths Between Soil Types	92
3-2-6	Non-Parametric Multiple Comparisons Test (Zar 1974) for Differences in Biomass Between Soil Types	92
3-2-7	Nutrient Analysis for Soil Productivity Test Samples	94
3-2-8	Classification of Variables for Analysis of Variance, Shrub Importance Values, Soils Versus Shrub Importance Values	97
3-2-9	Classification of Variables for Analysis of Variance, Herb Frequencies, Soils Versus Herb Frequency Percent	98
3-2-10	Classification of Variables for Analysis of Variance, Soil Characteristics, Soil Type Versus Characteristics	99
3-2-11	F-Ratios for Analysis of Variance	101
3-2-12	Soil-Soil Nutrient Correlations	102
3-2-13	Shrub-Shrub Correlations	104
3-2-14	Herb-Herb Correlations	107
3-2-15	Significant Correlations Between Species and Soil Characteristics (90% Confidence Interval)	109
3-2-16	Correlations Between Shrub Species Pairs and Correlated Soil Constituents (75 Percent Confidence Interval)	111
3-2-17	Correlations Between Herb Species Pairs and Correlated Soil Constituents (75 Percent Confidence Interval)	113
3-2-18	The Abundance of Soil Microorganisms on Grids 1 and 2, August 1975	116

Table Number	Table	Page
3-2-19	The Abundance of Soil Microorganisms on Grids 1 and 2, July 1976	117

Section 3.3 Vegetation:

Table Number	Table	Page
3-3-1	Vegetation Sampling Summary and Phytosociological Studies Exclusive of Intensive Study Plots	126
3-3-2	1975 Sample Numbers and Locations for Shrub Productivity Study	131
3-3-3	Decomposition Sample Location Pattern	133
3-3-4	Species Used in Herb Phenology Study	135
3-3-5	Stand Numbers and Vegetation Types for Areas Sampled as Part of the Broadly Based Sampling Program	137
3-3-6	Matrix of Similarity Values[1] for Sampled Pinyon-Juniper Woodland Stands	142
3-3-7	Matrix of Similarity Values[1] for Sampled Chained Rangeland Stands	145
3-3-8	Matrix of Similarity Values[1] for Sampled Upland Sagebrush Plots and Stands	148
3-3-9	Matrix of Similarity Values[1] for Sampled Bottomland Sagebrush Stands	152
3-3-10	Shrub Layer Species Importance Values[1] (Percents) for all Sampled Plots and Stands[2] Exclusive of Disturbed Sites for the 1975-1976 Shrub Sampling Period	171
3-3-11	Matrix of Similarity Values[1] for Sampled Vegetation Stands[2]	173
3-3-12	Average Similarity Values for Sampled Vegetation Stands	175
3-3-13	Current Live Standing Crop at Each of the Intensive Study Plots During 1976[1]	182
3-3-14	Standing Biomass at Each of the Intensive Study Plots During 1976[1]	183

Table Number	Table	Page
3-3-15	Litter and Prostrate Dead at Each of the Intensive Study Plots During 1976[1]	185
3-3-16	Current Live Standing Crop at Each of the Intensive Study Plots During 1975[1]	191
3-3-17	Standing Dead Biomass at Each of the Intensive Study Plots During 1975[1]	192
3-3-18	Litter and Prostrate Dead Biomass at Each of the Intensive Study Plots During 1975[1]	193
3-3-19	Shrub Standing Crop Estimates for Major Shrub Species in Each of the Intensive Study Plots for 1975	195
3-3-20	April and September 1976 Standing Crop Estimates for Major Shrub Species ($S\bar{y}$ = Standard Error of the Mean)	196
3-3-21	Shrub Standing Crop Estimates for Major Shrub Species in Each of the Intensive Study Plots for 1976	197
3-3-22	Productivity for Major Shrub Species at Each of the Intensive Study Plots for 1975 and 1976	198
3-3-23	Summary of Shoot and Twig Weight, Length, and Number Estimates for Mountain Mahogany and Antelope Bitterbrush (1976) in Pinyon-Juniper Woodlands and Chained Rangelands ($S\bar{y}$ = Standard Error of the Mean)	201
3-3-24	Mean Percent Decomposition of Leaf Samples and Cellulose Standards After 17 Months of Time in the Field[1]	204
3-3-25	Mean Percent Decomposition of Leaf Samples and Cellulose Standards After 22 Months of Time in the Field[1]	205
3-3-26	Decomposition Rates for Leaf Samples and Cellulose Standards at Each of the Intensive Study Plots (Values are in Percents/Month)	206
3-3-27	Estimates of Mean Leaf and Twig Litter Fall Rates in a Bottomland Sagebrush Community (Plot 4) and in Pinyon-Juniper Woodlands (Plots 5 and 6)	210

Table Number | Table | Page

Section 3.4 Animals:

3-4-1 Deer Pellet-Group Distributions and Densities 232

3-4-2 Mule Deer Browse Utilization, 1975-76 234

3-4-3 Browse Condition Based on Ocular Methods of Evaluation 235

3-4-4 Deer Mortality Results 237

3-4-5 Age-Class Composition of Deer Wintering Near Tract C-b 238

3-4-6 Results of Coyote Scent Station Surveys 241

3-4-7 Relative Abundance* of Medium-Sized Mammals in Four Habitat Types as Estimated by Tract Counts. The Data Combine Bi-Monthly Sampling Periods for Each Year of Baseline Study 243

3-4-8 Species List and Location of Capture of Observation of Small Mammals on Tract C-b, August 1974 - August 1976 252

3-4-9 Density Estimates (Animals Per Hectare) for Small Mammals on Grids 1 (Chained Pinyon-Juniper) and 2 (Pinyon-Juniper Woodland) August 1974 - August 1976 256

3-4-10 Percent Trap Success for Small Mammals on the Satellite Grids, September 1974 - August 1976 257

3-4-11 Total Number of Marked Animals on Grids 1 (Chained Pinyon-Juniper Rangeland) and 2 (Pinyon-Juniper Woodland) (Including Dense Lines) with Chi-Square Tests for Goodness of Fit Between Grids for the Period August 1974 - August 1976 269

3-4-12 Live Weights of *Peromyscus maniculatus* on Tract C-b, September 1974 - August 1976 278

3-4-13 Live Weights of *Eutamias minimus* on Tract C-b, September 1974 - August 1976 279

3-4-14 Live Weights of *Eutamias umbrinus* on Tract C-b, September 1974 - August 1976 280

Table Number	Table	Page
3-4-15	Home Range (2 Sigma) Values for Least Chipmunks and Deer Mice on the Chained Pinyon-Juniper Grid and the Pinyon-Juniper Woodland Grid	282
3-4-16	Mean Survivorship[1] (MOS) for Small Mammals on Grids 1 and 2, August 1974 - August 1976	285
3-4-17	Relative Frequencies of Small Mammal Diet Items, May 1975 - August 1976	288
3-4-18	Schedule of Baseline Data Collection on Birds at Tract C-b	292
3-4-19	Characterization of Strip Transects Sampled for Birds on Tract C-b	293
3-4-20	Common Bird Species Observed on Tract C-b[1]	301
3-4-21	Importance Values for Each Songbird Species Observed Along Strip Transects Conducted During May 1975 and June 1976, Tract C-b Shale Oil Project	305
3-4-22	Species Numbers, Densities, Diversities, and Dominance Indices for Avian Communities in Habitats During Two-Year Baseline Program[1]	308
3-4-23	Principle Wintering Species in the Four Primary Habitats on the Tract C-b Study Area	311
3-4-24	Results of Shorebird and Waterfowl Counts Conducted at P-L Ranch Pond During the Two-Year Baseline Program, Tract C-b Shale Oil Project	324
3-4-25	Results of Shorebird and Waterfowl Counts Conducted at W. Oldland Ranch Pond During the Two-Year Baseline Program, Tract C-b Shale Oil Project	325
3-4-26	Raptors Noted on the Tract C-b Study Area During the 1974 - 1976 Study Period	329
3-4-27	Relative Abundance of Owl Species Recorded on Tract C-b During 1974 - 1976	331

Table Number	Table	Page
3-4-28	Summary of Raptor Pellet Analysis 1975 - 1976, Tract C-b Shale Oil Project	333
3-4-29	Habitat Requirements of Important Bird Species on Tract C-b	341
3-4-30	Relative Abundance[1] of Reptiles on Grids 1 (Chained Pinyon-Juniper Rangeland) and 2 (Pinyon-Juniper Woodland) from June 1975 - August 1976	344

Section 3.5 Aquatic Ecology:

Table Number	Table	Page
3-5-1	Water Quality Standards, Recommended Values and Ranges in Piceance Basin Streams for Water Quality Parameters Being Studied	368
3-5-2	Light and Dark Bottle Productivity Estimates[1] for Stewart and Willow Lakes, July 1975 - July 1976	393
3-5-3	Periphyton Productivity[1] Estimates for Piceance Basin Stations, May 1975 - July 1976	395
3-5-4	Benthic Invertebrate Species Diversity (D), Equibility (E), and Redundancy (R) Values for Piceance Basin Stations, September 1974 - July 1975	409
3-5-5	Length-Age Relationship of Mountain Suckers Captured at Piceance Basin Stations, August 1974 - July 1976	413
3-5-6	Length-Age Relationship of Brook Trout Captured at Piceance Basin Stations, August 1974 - July 1976	419

SUMMARY

Oil Shale Lease Tract C-b lies within the pinyon-juniper ecosystem of the Piceance Basin in western Colorado. In order to meet the lease requirements and stipulations to describe the existing environment within the lease Tract and a one mile buffer zone and provide baseline date upon which to build a viable monitoring program, a group of studies of the major biological and closely associated parameters was undertaken. The studies to be discussed in Volume IV of this report series include studies of the microenvironment, soils, vegetation, terrestrial animals, and the aquatic environment within the Tract C-b study area.

S.1 Microenvironment

Microenvironmental studies were begun in March 1975. Twenty-one stations were established: four continuous recording sites and seventeen non-recording spot check stations. The four recording stations were located in the four major vegetation types. Various physical parameters were measured. Temperatures began warming in April with peaks in August and September and then declined. Yearly maximum temperature reached a mean value of $49^{\circ}C$; the mean minimum was $-17^{\circ}C$. Solar insolation appears to be the driving force for the differences in growing seasons between community types, and the effect of insolation is strongly influenced by the structure of the vegetation. Precipitation is greatest in winter, averaging 31 mm per month. Periods of the most significant moisture accumulation were May-June and January-March with 84 mm and 170 mm respectively. The late spring, early summer accumulation is significant for resumption of plant growth. There was a marked difference in precipitation patterns between the two years studied. Precipitation during the first year of the baseline, 1975, was greater during the summer months than it was in 1976. Precipitation during this second year was pronounced in early spring and notably low during summer. Soil water potential was lowest in woodland communities at -40 bars, chained rangelands also experienced relatively low levels of soil moisture tension (-25 bars) that may be limiting to some species. In bottomland and upland sagebrush communities, soil moisture did not drop below -15 bars until late summer or early fall.

Statistical analyses showed differences between the microenvironments of the stations and between the years studied. It was concluded that these differences were not due to total precipitation or soil moisture, but rather to the unique make-up of each vegetation type (i.e., vegetation and soils).

S.2 Soils

Soil studies were conducted to determine correlations between soil constituents and vegetation. Studies included soil surveys and mapping, examination of soil nutrients, determination of soil productivity, soil-plant interrelationships, and soil-biotic studies.

Seven soil series were identified from the Tract and mapped. Chemical and physical characteristics of the soils were analyzed. In productivity studies, no differences were noted between the soil types with respect to germination. However, growth and biomass accumulation were significantly higher in two types of soil (Redcreek - Rentsac Complex). There were no strong trends noted between species and soil characteristics. There appeared to be marked differences between woodland and range sites as a group and big sagebrush as another group. Chained rangelands were the most productive sites, attributed to the higher concentration of soil microorganisms in this vegetative type. Soil characteristics (chemical analyses) showed differences within the soil type and vegetation community classifications. In soil to soil interactions, inhibitory interactions that establish limiting soil nutrient factors and a controlling influence of toxic soil constituents were noted. Limiting soil nutrients included phosphorous and potassium. Toxic soil constituents were salts, sulfate, and nitrate. Negative correlations and positive correlations were noted between certain vegetation species. In addition to interspecific competition, species tolerance and avoidance of certain environmental conditions were noted. Soil fungi were the most active soil microorganisms with the greatest number found in surface layers. Actinomycetes were studied along with soil bacteria.

S.3 Vegetation

Vegetation studies were conducted in compliance with the requirements of the Shale Oil Lease Stipulations. In order to provide an adequate baseline description of the existing vegetation, a number of component studies were conducted. These component studies included a floral inventory, phytosociological studies, productivity studies, decomposition and litter-fall studies, herb phenology, shrub stem growth studies, and development of a vegetation map.

S.3.1 Flora

Tract C-b lies in a floristic transitional zone between the Rocky Mountains to the east and the Intermountain West-Great Basin region to the west. The flora of the Tract is composed of 230 species of vascular plants representing 54 families and 163 genera. Sixty-eight percent is composed of herbaceous perennials, although the Tract is characterized by pinyon-juniper woodland and open shrubland. No species identified from the Tract are considered to be endangered or threatened, and the flora of the Tract appears to be typical of the general region in western Colorado.

S.3.2 Plant Communities

Fourteen plant communities occur within the Tract C-b study area. These include:

S.3.2.1 Pinyon-Juniper Woodland

Pinyon-juniper woodlands are the most common and wide spread vegetation type in the Piceance Basin. Although over 50 percent of the pinyon-juniper woodland on the lease Tract has been removed through chaining by the BLM, it is still one of the most common and dominant vegetation types on Tract.

The dominant tree species in the woodlands are pinyon pine, Utah juniper, and Rocky Mountain juniper. The composition of the shrub layer within the woodlands varies with slope and exposure with big sagebrush dominant on the ridgetops; serviceberry, bitterbrush, and mountain mahogany dominating the hillsides, and snowberry dominant on north facing slopes.

The pinyon-juniper woodlands are one of the most stable vegetation types in the Piceance Basin with the oldest trees being more than 200 years old. Pinyon pine and juniper do not appear to be invading other vegetation types.

S.3.2.2 Chained Pinyon-Juniper Rangeland

Chained pinyon-juniper rangeland covers about 45 percent of the Tract and is generally restricted to ridges and gentle hillsides where bulldozer operation is feasible. The chained rangelands are ecologically unstable communities and are in successional stages leading to reestablishment of the pinyon-juniper woodlands. The dominant species include big sagebrush, bitterbrush, and saplings of pinyon pine and Utah juniper, with snowberry locally abundant.

Herbaceous cover in the chained pinyon-juniper averages 32 percent, about twice the value in the pinyon-juniper woodland. Common herbaceous perennials include Indian ricegrass, squirreltail grass, and western wheatgrass. Cheatgrass is the most common annual, but many other species also occur including goosefoot, stickseed, and tangy mustard.

S.3.2.3 Big Sagebrush Communities

Big sagebrush communities are widely distributed throughout the Piceance Basin and occur in two structurally different types.

S.3.2.3.1 Upland Sagebrush Communities

Upland sagebrush communities occur on broad ridgetops and in clearings within the pinyon-juniper woodland. The community is dominated by big sagebrush with occasional saplings of pinyon and juniper. Prickly pear is also common in many stands of upland sagebrush.

The herbaceous layer contains many species, including western wheatgrass, Junegrass, long-leaned phlox, hawksbeard, mariposa lily, clover, and microsteris, which occur at nearly 100 percent frequency. The upland sagebrush communities on Tract C-b apparently constitute an ecologically-stable vegetation type.

S.3.2.3.2 Bottomland Sagebrush Communities

Bottomland sagebrush communities typically occur on valley floors and alluvial fans of the gulches throughout the Piceance Creek basin. The best developed bottomland sagebrush stands on Tract C-b occur in Scandard Gulch and along the west fork of Stewart Creek.

The dominant species in these communities is big sagebrush with prickly pear and winter fat common in low densities. Other shrub species comprise a minor component of this association. The density of big sagebrush in the bottomlands is 1.7 times greater than that in the upland sagebrush communities.

The herb layer is dominated by the weedy annuals: cheatgrass, goosefoot, and stickseed; and the perennial mountain peppergrass, also a species characteristic of disturbed areas. However, the bottomland sagebrush community is not successional and disturbances to the association appear to favor the development of associations dominated by rabbitbrush rather than big sagebrush.

S.3.2.4 Douglas-fir Forests

Douglas-fir forests are a common vegetation type at higher elevations in the Piceance Creek basin. At the lower elevations, in which Tract C-b occurs, Douglas-fir stands consist of only a few scattered trees. They occur on steep north-facing slopes where more favorable cool and moist conditions prevail. Dominant shrub layer species include Gambel's oak and snowberry.

S.3.2.5 Mixed Mountain Shrublands

Mixed mountain shrublands represent some of the most widespread and abundant plant communities in the Piceance Creek basin. The mixed shrub communities are composed of numerous shrub species including Gambel's oak, serviceberry, mountain mahogany, bitterbrush, chokecherry, Juneberry, snowberry, and Oregon grape. The structure and composition of this vegetation type may vary considerably because many of these species may occur as the dominants depending on the slope, exposure, soil conditions, and moisture regime.

Herb-species composition is varied and includes numerous species characteristic of more mesic vegetation types. Low growing shrub species such as mountain lover and Oregon grape are also common in the herb layer.

The mixed shrub communities in their typical form represent stable communities with successional changes unlikely.

S.3.2.6 Bunchgrass Community

Bunchgrass communities occur primarily on steep talus deposits on the sides of major valleys. On Tract C-b, these communities generally occur as narrow bands between the bottomland sagebrush and the pinyon-juniper woodland.

The shrub layer in the bunchgrass communities is poorly developed with shadscale and four-winged saltbush occurring as dominant species in the stands along Piceance Creek. The herb layer is dominated by Indian ricegrass which reaches its maximum development in the bunchgrass community. Other common herb species include wild buckwheat, cheatgrass, and brickelbrush.

The bunchgrass communities on talus slopes represent ecologically stable communities, while those developed in other vegetation types following fire are successional and will eventually be replaced by pinyon-juniper woodland or upland sagebrush communities.

S.3.2.7 Marshlands

Because of the semi-arid nature of the Piceance Basin, marshlands are regionally uncommon and occur only on floodplains of major drainages. Several small marshes occur within the Tract C-b study area, but none occur within the Tract boundary. The vegetation in the marshes is composed primarily of perennial herbaceous aquatic and semi-aquatic plants. It is dominated by cattail, common reed, and numerous species of sedges and rushes with a few scattered small and inconspicuous willows.

S.3.2.8 Riparian Communities

Riparian communities are located along the sides of the major streams in the region. Within the study area, the best developed riparian areas occur along Piceance Creek, Willow Creek, and the lower portions of Stewart Creek. There are no riparian areas within the Tract boundaries.

The riparian vegetation is mostly restricted to stream trenches except in those areas where the banks slope gently to the streambed. The vegetation along the streams is composed of sedges, rushes, horsetails, grasses, marsh elder, checker mallow, and others. Willows tend to be small and isolated and of limited occurrence.

S.3.2.9 Great Basin Wild Rye Communities

Great Basin wild rye communities occurred in dense stands on the floodplains of the larger streams prior to settlement of European man in the Piceance Basin. In the Tract C-b study area, Great Basin wild rye stands are restricted to small floodplain areas along Willow Creek and the east fork of Stewart Gulch.

The dominant species in these communities is Great Basin wild rye with other common species being cheatgrass and mountain peppergrass. Big sagebrush also occurs occasionally in this vegetation type.

S.3.2.10 Rabbitbrush Communities

The distribution of the rabbitbrush community in the Tract C-b area is restricted to floodplain areas that have been disturbed since settlement. The rabbitbrush vegetation appears to constitute a successional vegetation type leading back to the big sagebrush vegetation type.

The shrub layer is dominated by rubber rabbitbrush with low numbers of big sagebrush as the only other shrubs in the vegetation type. The herb layer consists primarily of mountain peppergrass, western wheatgrass, and cheatgrass, with a variety of other weedy species.

S.3.2.11 Greasewood Communities

In the Piceance Basin, the greasewood community is restricted to valley bottoms and alluvial fans where local salt levels are high. In the Tract C-b study area, greasewood communities occur only on alluvial fans along Piceance Creek and constitute an ecologically stable vegetation type.

The dominant shrub layer species is greasewood with rabbitbrush as a secondary dominant. The herb layer is composed of relatively few species with the most common being the introduced species, crested wheatgrass and cheatgrass.

S.3.2.12 Agricultural Meadows

The agricultural meadows in the Tract C-b study area are restricted to floodplain areas along the major streams. These meadow associations are composed primarily of alfalfa and introduced pasture grasses.

S.3.2.13 Annual Weed Communities

The location of annual weed communities follows no pattern but rather they occur on sites related to industrial development or ranching disturbances. Dominant species on these sites include such weedy annuals as cheatgrass, white pigweed, tumble mustard, Russian thistle, and goosefoot. The most common perennials noted in disturbed areas were western wheatgrass and Indian ricegrass.

S.3.2.14 Aquatic Plant Communities

The ponds near Tract C-b support a lentic plant community dominated by pond weed (Potomogeton sp), and the Piceance Creek supports local concentrations of watercress forming small lotic communities.

S.3.3 Intensive Study Plot Studies

S.3.3.1 Herb Layer Composition

Frequency data obtained over the two year baseline survey indicate considerable consistency in frequency levels between years.

Annual plant species, as a group, showed the greatest differences between the two years being more frequent in 1975 than in 1976. Estimates of total herb cover were comparable between the two years except for the bottomland sagebrush which was higher in 1975 than in 1976. The observed differences in frequencies can be attributed to both environmental (cooler and more moist conditions in 1975 compared to the warmer and drier 1976, and the occurrences of a killing frost in June 1976) and experimental (observer) error.

S.3.3.2 Shrub Layer Structure and Composition

Frequency values for most species were comparable between the two years. In general, most sample sites increased slightly in cover from 1974 to 1976. Density values for some species, prickly pear and snake weed, were available. Big sagebrush and bitterbrush had higher densities while most species were not consistently higher or lower in observed densities over the sample period. Since significant shifts in shrub cover, frequency, and density would require more than two years, most of the variation observed should probably be attributed to sampling rather than to environmental changes.

S.3.3.3 Tree Layer

Tree growth at the intensive study plots was minimal during the baseline period with the utility of the data tempered by sampling difficulties.

S.3.3.4 Production Studies

While there were apparent differences in herb production between some treatments within the two chained rangeland plots, comparisons of peak standing crop data suggest few significant differences among treatment plots.

S.3.3.4.1 Herb Production

Comparisons of 1976 herb production in the major vegetation types on Tract C-b indicate that the upland sagebrush is the most productive (254±21 kg/ha/yr), followed by the chained rangelands (189±37 kg/ha/yr), pinyon-juniper woodland (132±22 kg/ha/yr), with bottomland sagebrush (113±20 kg/ha/yr) least productive. Differences noted in maximum standing crop between 1975 and 1976 indicate 1975 had a significantly higher productivity than did 1976. The difference between years appears to be related to temperature and precipitation differences during the growing season. Nineteen-hundred seventy-five tended to be cooler and more moist than 1976, thus providing conditions which are more conducive to plant growth. In addition, a severe frost in 1976 apparently reduced the overall productivity of the herbaceous species.

S.3.3.4.2 Shrub Production

Shrub production studies indicate that the bottomland sagebrush community is the most productive on the Tract (6929 kg/ha/yr). Mean shrub production was 17 times greater than production in the upland sagebrush vegetation type (415 kg/ha/yr), the second most productive type. The chained rangeland type was slightly lower in productivity (316 kg/ha/yr) than the upland sagebrush community, with the pinyon-juniper woodlands (91 kg/ha/yr) being the least productive community, in terms of shrubs, on Tract.

All sites show substantial reductions in shrub production in 1976 from the levels in 1975. As with the herb production discussed above, the reduction in shrub productivity may be a result of differences in the temperature and precipitation regimes between the two years.

S.3.3.5 Decomposition and Litter Studies

In general, big sagebrush leaves appeared to decompose most rapidly followed by mountain mahogany, serviceberry, and then the cellulose standards. However, this may be a function of the size of the individual materials (i.e., the big sagebrush leaves are the smallest and the cellulose standards are the largest of the test materials).

No one community type stood out as having consistently higher or lower decomposition rates.

Litter fall studies indicate that litter fall is highly variable in its distribution on the ground due primarily to canopy characteristics, with a seasonal range of 139 ± 8 g/m^2 to 83 ± 19 g/m^2 in some vegetation types. Turnover rates ranging from approximately 28 to 34 months were noted on Tract C-b. These rates may vary based on leaf tissue quantity and quality of soil in which the litter falls.

S.3.3.6 Herb Phenology Studies

There was a general tendency for a large percentage of the populations of perennial grasses to remain vegetative and produce few flowering heads. Forb species also produced few or no flowers during the sampling periods. The warm-dry growing season conditions may have been responsible for the limited flowering of the perennial grasses and the very limited flowering of the forbs.

S.3.3.7 Shrub Stem Growth Studies

Total stem growth of serviceberry was 3.1 to 4.6 times greater in the chained rangeland than in woodland sample plots. Apparent growth was greater in fenced plots than in open. This difference may be attributable to browsing pressure by large herbivores.

Total stem growth of mountain mahogany was also greater in the chained rangeland than it was in the pinyon-juniper woodland. Within vegetation communities, the fenced plots exhibited greater stem growth than did the open plots. These differences in apparent stem growth may also be attributable to browse pressure.

Stem growth studies of big sagebrush in both upland and bottomland sagebrush communities indicated that total stem growth in the fenced bottomland and upland plots was essentially the same. However, stem growth in the open bottomland plot was greater than that in the open upland plot. Within the upland site, stem growth was considerably greater in the fenced plot than in the open plot, but within the bottomland site stem growth was essentially the same in both plots.

The lack of differences between the fenced and open plots indicates that little browsing occurs in the bottomland plots, while at the upland site there appears to be enough sagebrush utilization to result in measurable difference between open and fenced plots.

S.4 Animals

S.4.1 Big Game

Mule deer are abundant on Tract C-b during winter, but are virtually absent in the area from mid-May to mid-September. During baseline studies, the height of the fall and spring migratory movements occurred on 18 October 1975 and 6 May 1976. Both dates are approximately one week earlier than were observed the year before. The duration of the fall and spring migratory movements, as observed on the study area, was approximately two weeks. Tract C-b is located within deer winter range and not on a travel route located between summer and winter ranges. During winter deer utilized chained rangeland more heavily than other habitats, but pinyon-juniper woodlands provided important cover as well as forage. Estimates of deer pellet-group densities were 377 and 475 per acre for the first and second year of baseline study in the chained rangeland habitat, and 260 and 373 for both years in the pinyon-juniper habitat. Differences between habitats during the same year and yearly differences between the same habitats were significant (P. 05). Shrub utilization studies indicated the deer population to be near carrying capacity. Shoot length measurements on antelope bitterbrush indicated 72 percent utilization in chained areas and 65 percent utilization in pinyon-juniper areas. Agricultural meadows north of Tract C-b attracted large numbers of deer in fall and spring, and nearby south-facing slopes were used by deer during times of deep snow. Road count studies indicated high numbers of deer near Tract C-b compared to most other areas along the 35 mile length of road that was traveled. Deer were more abundant during the second year of baseline study as indicated by road counts and by pellet-group counts. Most winter deer mortalities occurred in the small lateral draws at the lower elevations.

A few elk were present near the eastern boundary of the study area during March 1975. Occasionally, during the course of field investigations, elk fecal pellets were observed within the boundaries of the Tract, and most commonly in the pinyon-juniper and mixed mountain shrub habitats. Most of the fecal pellets observed were old and they were not abundant at any site. Small groups of elk were seen on several occasions during July and August 1975 at higher elevations to the south of the study area.

S.4.2 Medium-sized Mammals

Coyotes were relatively abundant near Tract C-b compared to other areas in Colorado, Utah, and Wyoming. Indices of 188 and 122 for the first and second year of baseline study were obtained using the Fish and Wildlife Service scent station survey. The high numbers of coyotes may be partially due to the large amount of deer winter kill which occurs in the area and the minimal amount of local predator control. The importance of coyote predation on deer or other potential prey species was not determined.

Cottontail populations were judged to be low during the first year of baseline study compared to other areas in Colorado with satisfactory desert cottontail habitat. A noticeable increase was observed in the late summer of the second year, however. The habitat with the highest abundance of cottontails was the bottomland sagebrush as indicated by track count surveys.

Information was limited regarding the abundance and distribution of the remaining medium-sized mammals identified on Tract C-b and precluded quantitative analysis. The remaining medium-sized mammals identified included the white-tailed jackrabbit, yellow-bellied marmot, muskrat, beaver, porcupine, bobcat, striped skunk, long-tailed weasel, raccoon, and badger.

S.4.3 Small Mammals

A greater number of species were trapped in chained pinyon-juniper (14) than in pinyon-juniper (7) or in secondary habitats such as pinyon-juniper rimrock, bottomland sagebrush, and mixed mountain shrub. The major factor contributing to this difference in small mammal diversity appeared to be habitat structure. In chained pinyon-juniper areas downed trees bulldozed into slash piles provided additional habitat for a variety of small mammals, and an increase in herbaceous vegetation resulted from the removal of the pinyon-juniper overstory. The deer mouse and least chipmunk were the most widely distributed species and occurred in the majority of habitat types present in the study area.

For all species combined, the general pattern of seasonal density fluctuations was low density in early spring (10-25 individuals/hectare; $\bar{x}$ = 18.1/hectare), followed by an increase in number during summer (15-32/hectare; $\bar{x}$ = 20.3/hectare), and maximum densities occurring in late summer - early fall (25-55/hectare; $\bar{x}$ 32.5/hectare). This general trend resulted from a combination of winter mortalities, spring reproductive effort, and late summer dispersal of subadults from spring litters. The deer mouse and least chipmunk were dominant species in terms of density, comprising 75-90 percent of the total density estimates in each trapping period. Voles, ground squirrels, and woodrats were less significant members of the small mammal community in terms of density.

Annual population fluctuations were also apparent from trapping efforts during baseline studies. Generally the fluctuations were attributed to fluctuations in food supply and weather which varied between years. Differences were noted in the magnitude of annual fluctuations. The deer mouse and least chipmunk exhibited relatively low magnitude annual fluctuations, fluctuating by factors of 1.5 - 3.5 between years, while vole species and the uinta chipmunk were subject to relatively high annual fluctuations (factors of 20 - 40). It was suggested that the magnitude of annual population fluctuations may be related to the relative sensitivity of species to factors which often act to control population growth, such as juvenile mortality, cessations of reproduction by adult females, and inhibition of reproduction in subadult females.

Although there was no significant difference in the total number of individuals trapped on Grid 1 [(1113) chained pinyon-juniper] and Grid 2 [(1022) pinyon-juniper], differences in the abundance of certain species were noted, e.g., deer mice 453/Grid 1, 582/Grid 2; least chipmunk 408/Grid 1, 256/Grid 2. It was suggested that variation in habitat structure between Grids 1 and 2, which had a substantial effect on species composition, was also the factor most responsible for these density differences.

Reproductive efforts of species which produced multiple litters, i.e., deer mouse, voles, commenced in spring (May-June) and continued with varying intensity throughout the summer. Several other species (chipmunks, ground squirrels, woodrats) produced only one litter per productive season in May-June. It was speculated that the initiation and success of reproductive activity was correlated to the presence of abundant green vegetation and favorable weather. The mean number of embryos (deer mice = 5.1; least chipmunk = 5.3) and placental scars (deer mouse 11.0; least chipmunk 5.6) correlated well with literature values.

Average live weights did not vary appreciably between years for the same species, age classes, and sex. Representative mean live weights were 21.5 gms for adult male deer mice and 33.0 gms for adult male least chipmunks; nonreproductive adult female deer mice 20.0 gms, nonreproductive adult female least chipmunks 34.0 gms. Because live weights were not subject to large magnitude annual fluctuations, it was indicated that long-term declines in average live weight might serve as a reliable measure of deterioration in habitat quality. In addition, live weights proved to be an accurate method of determining age classes for several species.

Home range size was calculated for the least chipmunk and the deer mouse. Representative home range sizes were 1.3 hectares for adult male least chipmunks and .63 hectares for adult male deer mice. No difference in home range size was noted between Grids 1 and 2 for either species. There was some indication that subadults exhibited larger home range size than adults and that home range size of males was larger than for females.

Survivorship and turnover rates of the deer mouse, least chipmunk, and uinta chipmunk were calculated and appeared to be in agreement with documented survivorship for similar species. The mean survivorship of the deer mouse after first capture was 1.3

months and high turnover rates were common, indicating that this winter active species may be a significant prey item and subject to high rates of mortality during winter months. The least chipmunk and uinta chipmunk exhibited longer survivorship (mean survivorship 1.6 - 1.9 months after first capture) and a lower turnover rate than the deer mouse. Their habit of remaining in their burrows for extended periods during winter months may have decreased their exposure to predators and unfavorable weather.

The relative frequency of diet items consumed by the deer mouse was generally correlated with the seasonal availability of those diet items. The relative frequency of arthropods consumed during spring and early summer ranged from 50-80 percent while vegetation was the dominant diet item consumed during periods when arthropods were scarce. The least chipmunk was also termed an opportunistic feeder but unlike the deer mouse this species consumed relatively large amounts of some diet items, e.g., seeds and vegetation, even when availability was low. This may have resulted from the least chipmunk habit of storing seeds and other vegetation for consumption during winter months.

S.4.4 Birds

The bird section of the volume summarizes methodologies employed in sampling the Tract avifauna and provides tabular, graphic, and descriptive information from 11 census periods when bird communities of principal Tract habitats were sampled. Characteristics of the songbird, gamebird, waterfowl, and raptor segments of the Tract's avifauna are described on a seasonal basis, and species considered to be the most important structural and functional avian components of Tract ecosystems are designated. Population characteristics and habitat requirements are discussed for these species. An appendix section provides a detailed description of census methodologies, a discussion on how data collected by the various techniques must be qualified, and a complete history of analyzed data on songbird-like species, waterfowl, and raptors. The Appendix also includes a listing of all species observed during the two-year baseline investigation program.

S.4.4.1 Songbirds

Although 136 bird species were observed within the study area during the 11 census periods, most songbird communities on the Tract are dominated by only two species, as indicated by a dominance index which summarizes relative densities for the two species achieving greatest numbers. At least 64 songbird or songbird-like species apparently nest on the study area. Substantial seasonal variations in density occurred for most habitats. The major factor which contributed to these variations was migratory behavior. Less than one-fourth of the songbird species which nest in the study area remain through the winter. Most of these species leave the Piceance Basin by late October and do not reappear until April and May. It was suggested that the high migratory propensity found operating on Tract C-b is generally typical of shrub steppe avifaunas due to low supplies of winter food (principally seeds). Literature accounts support this speculation.

The greatest diversity of birds was recorded during the late spring and early summer sampling periods; during this period, the diversity index (H') ranged from a low of 1.1 in riparian meadow (April 1976) to a high of 2.4 in pinyon-juniper woodland (June 1976).

Comparisons of density estimates for 1975 and 1976 breeding seasons indicated that densities for principal breeding species differed significantly between the two years in three principal habitats (riparian/agricultural meadow, pinyon-juniper woodland, and bottomland sagebrush, with reductions in densities in 1976 of 2.2, 2.4, and 2.4 birds/ha respectively). These differences are felt to be attributed in part to decreased grass, forb, and shrub productivity, and to a decreased number of terrestrial arthropods in the 1976 breeding season, thus, lowering food availability for both herbivorous and insectivorous birds nesting in the study area.

It is anticipated that species composition of the breeding bird communities will remain stable from year to year in the absence of major disturbances in all habitats except the chained pinyon-juniper woodland. There, normal vegetative succession is expected to influence changes in bird species composition and density as it did in 1976, when 11 breeding bird densities increased from 4.4 birds/ha in 1975 to 6.4 birds/ha in 1976.

Based on average densities of birds over 11 census periods, the pinyon-juniper woodland habitat supported the greatest number of birds (mean density = 7.2 birds/ha); the riparian meadow habitat averaged the second highest density (6.6 birds/ha); while the upland transition habitat ranked the poorest (2.4 birds/ha).

S.4.4.2 Upland Gamebirds

Two species of upland gamebirds, the mourning dove and sage grouse, were observed in the study area. Sage grouse sign was observed only once during baseline studies. Mourning doves were recorded in every habitat on the Tract. Average nesting densities during the breeding season were highest in pinyon-juniper rangeland (0.2 birds/ha) and lowest in bottomland sagebrush (0.1 birds/ha). Flocking behavior, occurring during the fall, resulted in high densities of mourning doves in the riparian meadow habitat along Piceance Creek (0.6 birds/ha).

S.4.4.3 Waterfowl and Shorebirds

Twenty-four waterfowl and shorebird species were recorded in the study area. Fifty-four percent are winter residents or migrants, and 11 species were found to be nesting in the area. During winter mallard, green-winged teal, and American wigeon were the most abundant species in the Tract vicinity. The mallard and green-winged teal are also the only abundant permanent residents in the study area. Other common, summer-nesting species include: spotted sandpiper, Wilson's phalarope, and cinnamon teal. Waterfowl populations were concentrated along Piceance Creek and its associated ponds; however, the scarcity or absence of open water and aquatic vegetation limited waterfowl densities and usage in the study area. Waterfowl usage was highest on the P.L. Ranch pond where peak usage of 45.7 average Bird-Use Days (ABUD) was recorded in the fall of 1974. Lower usage was recorded in fall of 1975 (18.0 ABUD).

Results from the two-year waterfowl surveys indicated that waterfowl utilization along Piceance Creek is relatively high compared to other areas in the Piceance Basin.

S.4.4.4 Raptors

Eleven diurnal hawk, vulture, and eagle species; eight owl species; and the common raven were recorded in the study area. Nests of four of the 20 species (red-tailed hawk, golden eagle, great horned owl, and common raven) were located in the Tract vicinity. At least 12 other raptorial species are expected to nest in the region. Fourteen of the 20 raptor species recorded on the study area winter there. The rough-legged hawk, golden eagle, bald eagle, and common raven were the most abundant diurnal wintering species.

Most wintering diurnal species made extensive use of the riparian areas along Piceance Creek bottomland sagebrush and chained pinyon-juniper woodland because of abundant prey and suitable hunting conditions. Dominant food items of wintering marsh hawks, buteos, American kestrels, and ravens were voles and deer mice. Density changes in these small mammals probably influence the size of diurnal raptor populations. Bald eagles and golden eagles apparently rely heavily on mule deer carrion and lagomorphs during winter, with the size of their wintering range dependent on prey density.

Red-tailed hawks, marsh hawks, American kestrels, ravens, and golden eagles were the most common diurnal raptors present during the breeding season. Nesting activity generally is initiated during March, and by April the majority of the study area's diurnal breeding raptors are present. Pinyon-juniper woodland and rimrock habitats provide the most abundant nesting sites within the study area. Summer food habit studies indicate that important raptor food items during the breeding season are voles, lagomorphs, pocket gophers, and deer mice.

Eight owl species were recorded in the study area. The great horned owl and screech owl were the two most abundant species observed, and both were recorded as permanent residents. Four other species (long-eared owl, short-eared owl, saw-whet owl, and pygmy owl) winter in the area in small numbers. Vole species are the most common prey of owl species based on food preference studies. In general, owl species observed in the study area appeared to either overwinter in their summer nesting area or to migrate out of the region during severe winters.

S.4.5 Amphibians and Reptiles

Reptiles were relatively uncommon in the study area. The relative abundance of reptiles observed on 2.72 hectare grids per observation period ranged between 5-22 with a mean of 11.6 on Grid 1 (chained pinyon-juniper) and 3-14 with a mean of 6.5 per observation period on Grid 2 (pinyon-juniper). Sagebrush lizards were the most abundant lizard on both Grid 1 (4-18/grid; $\bar{x}$ = 9.2) and Grid 2 (3-14/grid; $\bar{x}$ 6.5). The higher relative abundance of lizards on Grid 1 was attributed to the increased diversity in habitat structure in chained pinyon-juniper due to slash piles.

Amphibians were also relatively rare in the study area due to the limited extent of aquatic habitat. The leopard frog was the most common species observed in the study area and appeared to be most abundant near Piceance Creek and agricultural meadows.

S.4.6 Terrestrial Arthropods

The relative abundance of ground dwelling arthropods was generally highest in pinyon-juniper woodland during baseline studies (Grid 2 $\bar{x}$ = 51.5 individuals/100 pitfall days; Grid 1 $\bar{x}$ = 26.5 individuals/100 pitfall days), while species diversity was highest in chained pinyon-juniper (Grid 1 $\bar{x}$ = 3.0075; Grid 2 $\bar{x}$ = 2.1255). Higher species diversity in chained pinyon-juniper was due to the presence of seven herbivorous arthropod species not observed in pinyon-juniper. It was suggested that a greater abundance of herbaceous vegetation in chained pinyon-juniper was responsible for the greater number of herbivorous species.

The diversity of arthropods collected from shrubs varied between major browse species with serviceberry ($\bar{x}$ = 2.8) and big sagebrush ($\bar{x}$ = 2.7) supporting similar diversities and mountain mahogany ($\bar{x}$ = 2.25) hosting a much lower diversity. Many of the insects hosted by serviceberry were classified as defoliators.

These findings were consistent with published accounts of arthropod infestation of shrubs on western big game ranges which state that mountain mahogany appears to be relatively free of attack by insects and that serviceberry hosts numerous defoliators and stem insects.

Peak numbers of arthropods, 80-90 percent of which were classified as herbivores, were collected from all three major browse species (serviceberry, mountain mahogany, big sagebrush) during periods of maximum productivity. The occurrence of high numbers of arthropods was apparently related to the presence of succulent leaves and other plant parts. This finding was also consistent with previous studies which indicate that herbivore response to shrub phenology was the primary force influencing shrub dwelling arthropod numbers during the vegetative growing season. Late season productivity and delayed leaf senescence was apparently responsible for relatively high numbers of arthropods hosted by big sagebrush late in the growing season (September) when other shrub species hosted relatively few arthropods.

S.5 Aquatics

Aquatic studies were designed to provide data on water quality, sediments, plankton, periphyton, benthic invertebrates, fish species, and springs and seeps. Monthly collections were begun in August 1974. Sampling was reduced to a bimonthly program in January 1975 and continued through July 1976. Stations were established on the streams in the Tract vicinity (Piceance, Willow, and Stewart Creek), and on the White River.

Water quality of the streams in the Tract vicinity was marginal with respect to recommended standards (McKee and Wolf 1971, EPA 1972, 1975) for aquatic life. At some time during the two-year study, 10 of the 31 water quality parameters examined exceeded the recommended limits for aquatic life referenced above. High runoff in the spring resulted in heavy siltation loads. In addition, irrigation practices and return flow altered normal flow rates and added to degradation of water quality.

Plankton were not analyzed during the study except for light and dark bottle productivity estimates conducted in the lakes. Much of the phytoplankton that was present was the result of scouring of periphyton and was of minor significance with regard to primary productivity compared to periphyton and aquatic plants. Plankton primary productivity determined from lake stations was generally low, ranging from 0 to 213 mg C fixed/m^3.

Periphyton species collected consisted of green algae, diatoms, blue-green algae and euglenids. The greatest abundance occurred in summer and fall. Productivity estimates were made for all stations, and ranged from .0067 to 4.1507 grams ash free dry weight/ m^2/day.

Aquatic invertebrates collected at all stations were comprised of annelids, arthropods, and molluscs. Arthropods were most numerous. Species diversity, mean biomass equibility, redundancy and dispersion values were calculated. These indicated the downstream portions of Piceance Creek were poorer habitat and supported less variety of species than the other portions of the streams studied. Based on Lagler's (1956) food grade categories, most stations were in the poor food grade the majority of the time. There were seasonal fluctuations in all of the species collected.

The most abundant fish species in the streams studied were: Brook trout (Salvelinus fontinalis), mountain sucker (Catostomus platyrhynchus), and speckled dace (Rhinichthys osculus). Estimates of abundance per 100 meter stretch of stream ranged from 0 to 14 for brook trout, 17 to 101 for mountain sucker, and 7 to 115 for speckled dace. Brook trout abundance in the study area based on tag returns was estimated to be from 450 to 1,032 fish. Data on length-frequency, age, growth, fecundity, and food habits were compiled for the major species collected.

Twelve springs and seeps were identified and inventories of benthic invertebrates and water quality were conducted on a seasonal basis. Species collected were similar to those taken in stream studies.

1 INTRODUCTION

Volume IV of the Baseline Report Series for Oil Shale Lease Tract C-b discusses the ecological studies conducted on Tract C-b and the designated study area within one mile adjacent to it. These studies were designed to provide a description of the existing pre-development environment within the study area, and to further provide baseline data to be used in monitoring changes in the biota as a result of shale oil development. The studies were also designed to meet the lease requirements and stipulations as defined in 1974.

The parameters selected for study were those providing the most descriptive data on major structural ecosystem components within the fiscal resources available. Selected parameters emphasized variables (i.e., biomass, densities, abundance, temperature, precipitation, and soil moisture) rather than processes (i.e., photosynthesis, nutrient flow, herbage consumption), although some process parameters were studied (litter decomposition and plant productivity). In addition to the usefulness of the selected parameters in describing the existing environment on Tract C-b, consideration was given to their value in a monitoring program. Some parameters were judged to be useful only for the description of the existing environment, while others would also be useful in monitoring because of their relatively low natural variability, relative ease of measurement, and/or sensitivity to expected environmental perturbations.

Oil Shale Lease Tract C-b lies in the Piceance Basin of Colroado. The area is a transition zone between the cold desert floras of the Great Basin and Intermountain West and the montane forests of the Rocky Mountains. It is dominated by a pinyon-juniper ecosystem characterized by open woodlands and shrub communities. The regional vegetation types which characterize the Basin were differentiated in the Pleistocene and have remained relatively unchanged to the present day.

Studies on microenvironmental parameters on the C-b Tract provide valuable data on a variety of factors that will be useful in assessing changes in vegetation structure, animal populations, or activity patterns. Microenvironmental data may also be correlated with changes in functional components of the C-b ecosystem that may occur following shale oil development.

The soil studies conducted in conjunction with the biological baseline studies on Tract C-b provide extensive data on nutrient availability, toxic levels of some geochemical constituents; soil productivity, based on a standard laboratory seed stock; and soil biota including bacteria, actinomycetes, and fungi. The results of these studies can be considered in future analyses of data collected through monitoring programs conducted during operation and following completion of the Shale Oil Project.

Tract C-b, including the adjacent study area, is within the pinyon-juniper ecosystem of the Piceance Basin. Vegetation studies include: 1) the development of a floristic list of species present; 2) phytosociological studies to determine structural features and distributions of the plant communities, and to provide validation for the vegetation map; 3) productivity studies to provide background data on seasonal biomass accumulation; 4) decomposition and litter fall studies to provide estimates of nutrient turnover rates and soil microorganism activity; 5) herb phenology studies to provide baseline developmental time frames of herbaceous species; and 6) shrub stem studies to provide seasonal change data on shoot elongation, flowering time, and senesence of major shrub species, as well as to allow evaluation of individual shrub responses to mule deer browsing activities.

Wildlife population levels prior to the advent of European man into the Piceance Basin are unknown. However, anecdotal information indicates that major changes in population levels occurred with major declines as well as apparent recovery in some important species such as elk, bison, mule deer, wolf, and mountain lion (Volume I, Chapter 3). Many of these changes are probably related to vegetation changes brought about by extreme overgrazing and various levels of hunting pressures on such species as the elk, bison, and antelope. The Piceance Basin mule deer herd is presently a major resource from a recreational viewpoint and therefore was a major focus of the C-b baseline big game studies. The studies of the deer herd activity within the Tract C-b study area included habitat utilization and movement patterns, as well as studies of mortality.

The study of medium-sized mammals was primarily oriented toward collection of data on presence and absence of these taxa with estimates of relative abundance when the data allowed such analyses. The small mammal studies on Tract C-b provide baseline data on a variety of population parameters for the most abundant species on Tract. The parameters analyzed include population densities, home range, reproduction, seasonal trends in abundance, longevity, food habits, and habitat preferences.

Studies of bird species utilizing Tract C-b on a resident, seasonal, or transient basis included seasonal censusing of songbirds, upland game birds, waterfowl, and raptors as well as defining the habitat requirements of the principle species within the study area. Major emphasis was placed on those species having limited distributions and being most susceptible to changes in the environment or occupying a relatively sensitive position in the food chain. Raptor species were among those analyzed in detail.

Reptiles and amphibians were observed for presence or absence and, for selected species, relative abundance.

Ground dwelling and arboreal arthropods were sampled to provide data on relative abundance, habitat requirements, and seasonal population composition. Such studies provide information on relationships between arthropod species and various other components of the food web within the Tract C-b ecosystem.

The aquatic studies conducted as a portion of the Tract C-b baseline studies provide data on fish species, benthos, periphyton and biologically important water quality parameters in the White River, Piceance Creek, and associated tributaries and ponds. Aquatic systems are sensitive to changes in salinity, pH, and other factors associated with the possible contamination of surface and ground water related to the development of Tract C-b.

2.1 Lease Requirements and Stipulations

The environmental stipulations appended to the C-b lease established certain requirements relating to the collection of biological data. The stipulations generally required that biological studies be conducted in order to: (1) establish a baseline record of biological conditions existing prior to oil shale development, and (2) establish a monitoring program that will provide a record of changes from those conditions existing prior to development.

Biological studies and studies related to biota were required in the general areas of flora and fauna, and soils. Flora and fauna study requirements include:

(a) "studies of the flora and fauna of the leased lands and of all other lands lying within a mile of the leased lands, and of all lands to be used for disposal of residues from mining and processing oil shale..."

(b) studies of... "aquatic habitat as far downstream as the Mining Supervisor shall require."

(c) studies of ecological relationships, such as migration patterns of birds, mammals, and fish, and interrelationships between plants and animals.

Required studies were to obtain information on the distribution, density, and condition of the flora; and on the species of fauna present, their distribution, and relative abundance, at bimonthly intervals.

Soil survey and productivity assessment requirements include:

(a) A soil survey and productivity assessment on the leased lands proposed for disturbance under the detailed development plan.

Required studies will include maps, tables, and reports describing soil types; soil horizons and their thicknesses; strike and dip of soils; associated slopes; solar exposure of soils; vegetation cover; and erodibility of soils.

2.2 Baseline Study

2.2.1 Objectives

The general requirements of the environmental stipulations were evaluated and interpreted in 1974 by the staff of the C-b Shale Oil Project, their consultants, and the United States Geological Survey. The basic program was designed with the general concurrence of all groups involved, with some modifications of the program expected. The goal was to compile data in order to determine the conditions and their interrelatedness existing prior to any development operations, so that monitoring conducted before, during, and subsequent to the development would provide a record of changes, if any, from conditions existing prior to development. The baseline data were collected for a period of two years.

2.2.2 Physical Environment

Lease requirement programs dealing with the physical environment included studies of surface and ground water (discussed in Volume II), air quality (discussed in Volume III), and a soil survey and productivity assessment. In order to fulfill the requirements of the lease in the general area of effects of the physical environment on biota, with particular attention given to the requirement to study ecological interrelationships, studies to determine the condition of soils and the climatic factors operating within vegetation and habitat were initiated.

Soil studies included a soil survey conducted by the Soil Conservation Service (SCS). The soil survey identified seven major soil series on the Tract and surrounding one mile area. The soils surveyed were classified, mapped, physically described, and associated with vegetation types. In addition, all soils were sampled by horizon; samples were then analyzed for a suite of physical and chemical characteristics, including general agronomic characteristics, trace element analysis, and radioactivity analysis. Major soil series were also sampled and subjected to a productivity assessment. The studies of climatic and other environmental conditions within the vegetation consisted of a network of microenvironmental recording stations that obtained data on air and soil temperature, precipitation, wind speed and direction within the vegetation, net radiation, relative humidity, and potential evaporation.

2.2.3 Vegetation

Vegetation studies were initiated on Tract C-b in order to define the vegetation types occurring on Tract, the compositional nature of those vegetation types, and to compile a floristics list of all species present (including rare and endangered species). A vegetation map of the Tract and one-mile surrounding area was produced using aerial photography verified with ground reconnaissance. The composition or phytosociology of vegetation types occurring on the Tract were studied using two general approaches. Permanent, fenced vegetation plots were established in each of the four major vegetation types on Tract. At these permanent locations, species frequency, density and cover were determined for herbaceous and shrubby vegetation. Tree cover and frequency were also studied in forested sites. Production estimates for herbs and shrubs were also determined in the permanent locations, as were decomposition, litter fall, and herb phenology. Additional sampling of vegetation was also conducted throughout the Tract and the surrounding area. These samplings obtained additional information on major vegetation types, as well as providing basic information on vegetation types more limited in areal distribution.

2.2.4 Wildlife

Studies to obtain baseline information on terrestrial wildlife species and avifauna were conducted on the Tract and the surrounding area. Terrestrial wildlife studies included big game, medium-sized mammals, small mammals, reptiles, amphibians, and terrestrial arthropods. Big game studies were concentrated on mule deer. Information obtained from these studies includes numbers of deer, deer natality and mortality, information on deer migration, and habitat utilization. Medium-sized mammals studies were concentrated on lagomorphs and coyotes. Inventories of other species present were also conducted. Small mammal live trapping programs were conducted to determine population sizes, reproductive cycles, and food habits of important small mammals. Terrestrial arthropods and reptiles were captured in pitfalls located within the small mammal trapping grids. Shrub dwelling arthropods were also sampled within these grids. Amphibians were observed and recorded opportunistically during related field activities. Avifauna studies were separated into three large groups: songbirds, waterfowl, and raptorial birds. Songbird censuses were accomplished on the Tract and in the one-mile surrounding area. Systematic sampling of migratory waterfowl populations was also accomplished. Raptorial birds were studied through siting methods, analysis of nesting success, and pellet analysis.

2.2.5 Aquatic Ecology

In order to assess the aquatic biota of the Tract and surrounding areas, and in aquatic habitats downstream from the Tract, stations along the Piceance Creek and its tributaries in Willow, Scandard, and Stewart Gulches were established, as well as stations at springs, seeps and ponds that feed these tributaries. Sampling was also accomplished on the White River. At these aquatic locations sampling was systematically conducted on benthos, periphyton, plankton, bacteria, and fish. Water quality samples were also obtained at these sites, as well as bottom sampling for sediment analyses of trace elements.

3.1 Microenvironment

Microenvironment refers to phenomena operating in the zone of plant growth. This zone extends from the maximum height attained by plants to the level of the boundary between soil and parent material.

Microenvironmental measurements were initiated on and around Tract C-b in early March of 1975 when stations were established in characteristic plant communities. In the microenvironmental network four installations are continuous recording sites; seventeen stations are non-recording, spot-check stations containing instruments which are read periodically. Four of these stations are located at the recording station sites.

3.1.1 Rationale

Microenvironmental parameters of important vegetation types have been measured during the baseline period to determine the level of physical conditions at which many biotic components of the Tract C-b systems operate. The chosen parameters include major components of climate and microenvironmental factors, such as soil temperatures and moisture regimes.

The physical characteristics of the microenvironment include ambient air temperature in the plant canopy, surface temperature (of litter or soil), soil temperatures representative of the rooting depth of plants, precipitation in the plant canopy, potential evaporation, soil moisture, soil moisture capacities (at -15 and -1/3 bar), net radiation, humidity, wind speed and direction, and soil chemistry.

The significance of these parameters to the field of ecology lies in the area of limiting factors. Limiting factors are those environmental conditions which may limit the growth of vegetation, either in quantitative terms (such as standing crop of an area or density of a species of plant) or in distributional terms regarding the presence or absence of species. Thus, a knowledge of microenvironmental conditions helps explain the dynamics of differing discrete vegetational units. The influence that microenvironmental conditions exert on vegetation is extended to the carrying capacity of land units and to the characteristics of vegetation that form habitat for mammals, avifauna, arthropods, and reptiles. In this way the microenvironment may have far reaching effects on all biota.

The microenvironment of an area is a composite, being the sum of many characteristics of climate and soil interacting with vegetation structure. Vegetation exerts major influences on the microenvironment. Vegetation regulates the amount of solar insolation reaching the surface, and influences air movement patterns near the ground, thus regulating temperatures and diurnal changes in temperature as well as evaporative loss from the soil surface and evapotranspirational loss. Vegetation also influences the moisture content of air within the canopy. Soil moisture is affected by vegetation through the action of plants intercepting rainfall.

Microenvironmental factors often acting as limiting factors to vegetation are temperature and moisture. As previously noted, these limiting factors are the product of complex interactions. Ambient air temperature and precipitation tend to be more directly related to climate than are other microenvironmental characteristics, such as soil moisture, soil temperature, and surface temperature.

Temperature is limiting to plant growth through either its range of maxima or minima or the interaction of both. Temperature may influence germination, resumption of perennial growth, growth duration (and, thus, productivity), seed set, plant water balance, and soil water conditions individually or in combination.

Moisture may be limiting because nutrients are supplied through plant root/soil water interactions, and because of its importance to plant metabolism in general. Precipitation and soil water availability may determine plant community composition and plant productivity.

3.1.2 Objectives

The information derived from the measurement of microenvironmental parameters forms a basis for defining the conditions that affect the distribution and productivity of vegetation assemblages. This information can also be used in determining potential trends in the microenvironments of distinct vegetation types. These data will enable distinctions to be made between these natural trends and changes brought about by oil shale development. The information obtained from microenvironmental studies, in combination with other studies in the baseline program (i.e., plant productivity studies), will impart a knowledge of conditions that control the growth and productivity of vegetation and will aid in understanding year to year differences, as well as the long term trends in critical vegetation parameters.

3.1.3 Experimental Design

3.1.3.1 Measurement of Parameters

The microenvironmental network is composed of twenty-one stations located on and off-Tract. Four of the stations are recording installations; the remaining seventeen stations are equipped with instruments which must be read periodically. The specific types of measurements made at each site are detailed in Table 3-1-1; each site is located and described in Figure 3-1-1.

The four recording stations were located in each of the four major vegetation types on Tract C-b (pinyon-juniper woodland, chained pinyon-juniper rangeland, upland sagebrush, and bottomland sagebrush). Sites were chosen according to vegetation type along with proximity to sites on which extensive sampling was being accomplished for vegetation and mammalian parameters. Three of the four stations are located immediately adjacent to permanent vegetation study sites; the third site is located within one of the two small mammal trapping grids. Basic microenvironmental parameters are instrumented at all sites. These parameters include air and soil temperatures, precipitation, soil moisture, snow depth and density, wind speed and direction, and evaporation. In addition, the chained pinyon-juniper rangeland site is equipped to obtain data on net radiation and relative humidity. This site was chosen for these additional parameters because of the extensiveness of this vegetation type on Tract C-b.

The seventeen spot-check stations were established to obtain microenvironmental information for the four major vegetation types, and therefore act as a check on potential variation in microenvironmental conditions within the four types. They also served as a means to establish a data record for the microenvironments of several minor but important vegetation types. Many of the same general parameters were measured at these sites (Table 3-1-1). Instrumentation at these sites is read at biweekly intervals.

In addition to the recorded parameters, a number of soil characteristics important to microenvironment were established at each site. These include percent field capacity (-1/3 bar), percent permanent wilting coefficient (-15 bar), and soil texture.

3.1.3.2 Statistical Comparisons of the Four Microenvironmental Stations

Analysis of variance was used to test the differences observed in the microenvironmental characteristics of the four major vegetation types on Tract C-b, for statistical significance, and interaction between the factors. The Newman-Keuls test was also used to locate where the differences occur.

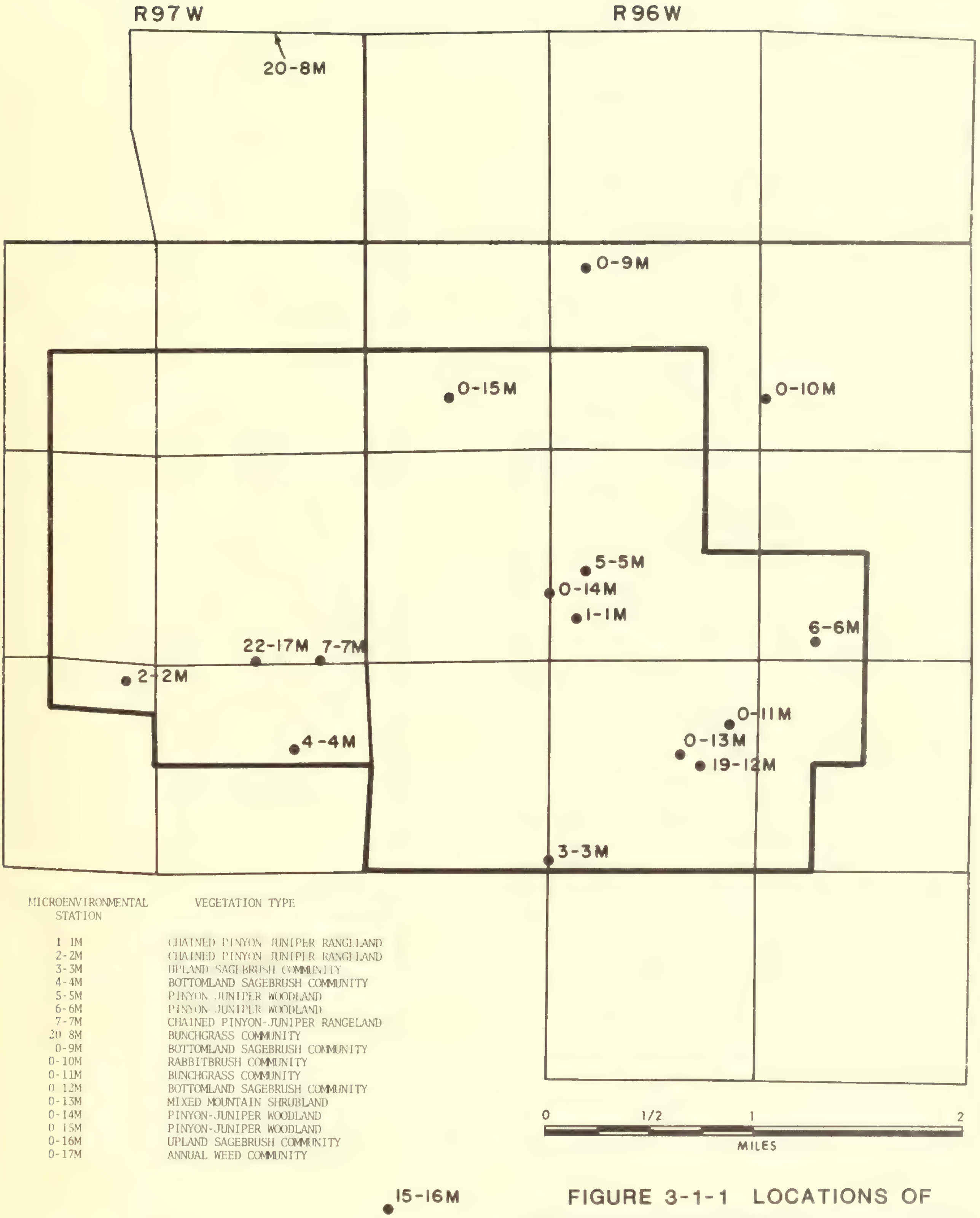
Table 3-1-1

MICROENVIRONMENTAL INSTRUMENTATION

Data Operation	Satellite Areas	Continuous Recording
(1) Free Air Temperature	X	C
(1) Soil Temperature		C
(2) Min-Max Temperature	X	
(5) Soil Moisture	X	X
(1) Wind Speed/Direction		C
(3) Relative Humidity		C
(3) Solar Radiation (Net)		C
(5) Snow Depth, Density Distribution	X	X
(2) Evaporation	X	X
(4) Precipitation	X	C

(1) At four permanent stations (chained pinyon-juniper rangeland, pinyon-juniper woodland, bottomland sagebrush and upland sagebrush)
(2) At ten relocatable sites (potential instrumentation up to 16)
(3) At one site only, permanent station (chained pinyon-juniper rangeland)
(4) At four permanent stations and ten relocatable sites
(5) At 12-16 permanent sites (four of these overlap with one)

C - Continuous Recording
X - Periodic Record



MICROENVIRONMENTAL STATION	VEGETATION TYPE
1-1M	CHAINED PINYON-JUNIPER RANGELAND
2-2M	CHAINED PINYON-JUNIPER RANGELAND
3-3M	UPLAND SAGEBRUSH COMMUNITY
4-4M	BOTTOMLAND SAGEBRUSH COMMUNITY
5-5M	PINYON-JUNIPER WOODLAND
6-6M	PINYON-JUNIPER WOODLAND
7-7M	CHAINED PINYON-JUNIPER RANGELAND
20-8M	BUNCHGRASS COMMUNITY
0-9M	BOTTOMLAND SAGEBRUSH COMMUNITY
0-10M	RABBITBRUSH COMMUNITY
0-11M	BUNCHGRASS COMMUNITY
0-12M	BOTTOMLAND SAGEBRUSH COMMUNITY
0-13M	MIXED MOUNTAIN SHRUBLAND
0-14M	PINYON-JUNIPER WOODLAND
0-15M	PINYON-JUNIPER WOODLAND
0-16M	UPLAND SAGEBRUSH COMMUNITY
0-17M	ANNUAL WEED COMMUNITY

FIGURE 3-1-1 LOCATIONS OF MICROENVIRONMENTAL STATIONS

3.1.3.2.1 Four-Factor Analysis of Variance

Three vegetation types, upland sagebrush, bottomland sagebrush, and pinyon-juniper woodland, were tested where the variable is the microenvironment (measured in terms of ambient, surface temperature and soil temperatures at -20 and -60 cm and precipitation). The test only involved three stations because of a lack of data, from July 1975 to May 1976, on two parameters, at the chained pinyon-juniper rangeland station. All five of the previously mentioned parameters were used in this test. The following hypotheses were tested:

1. Ho: The microenvironments of the three stations are the same.

   Ha: The microenvironments of the three stations are not the same.

2. Ho: There is no difference between the microenvironments of 1975 and 1976.

   Ha: There is a difference between the microenvironments of 1975 and 1976.

3. Ho: Microenvironmental differences between the stations are independent of differences between the years 1975 and 1976 (i.e., testing for absence of interaction).

   Ha: Microenvironmental differences between the stations are not independent of differences between the years 1975 and 1976.

4. Ho: There is no interaction between the effect of the parameters, years (1975-1976) and the vegetative types on the microenvironment.

   Ha: There is an interaction between the effect of the parameters, years (1975-1976) and the vegetative types on the microenvironment.

3.1.3.2.2 Three-Factor Analysis of Variance

The four major vegetation types on Tract C-b (see Vegetation, Chapter 3, Section 3) were tested where the variable is the microenvironment (measured in terms of ambient surface, and -20 cm soil temperatures). Only three parameters, ambient, surface and -20 cm soil temperatures, were used in this test due to the lack of data for the remaining two parameters as previously mentioned. The following hypotheses were tested:

1. Ho: The microenvironments of the four stations are the same.

   Ha: The microenvironments of the four stations are not the same.

2. Ho: There is no difference between the microenvironments of 1975 and 1976.

   Ha: There is a difference between the microenvironments of 1975 and 1976.

3. Ho: Microenvironmental differences between the stations are independent of differences between the years 1975 and 1976 (i.e., testing for absence of interaction).

   Ha: Microenvironmental differences between the stations are not independent of differences between the years 1975 and 1976.

4. Ho: There is no interaction between the effect of the parameters, years (1975-1976) and the vegetative types on the microenvironment.

   Ha: There is an interaction between the effect of the parameters, years (1975-1976) and the vegetative types on the microenvironment.

3.1.3.2.3 Single Factor Analysis of Variance

The four major vegetation types on Tract C-b were tested where the variable is the microenvironment (in one test measured in terms of precipitation and in the other test measured in terms of soil moisture). The following hypotheses were tested for both analyses:

Ho: The microenvironments of the four vegetation types are the same.

Ha: The microenvironments of the four vegetation types are not the same.

3.1.3.2.4 The Newman-Keuls Test

A multiple comparison was made to test if any of the four stations were the same. The following hypotheses were tested:

1. Ho: $\mu 1=\mu 4$
2. Ho: $\mu 1=\mu 3$
3. Ho: $\mu 1=\mu 2$
4. Ho: $\mu 2=\mu 4$
5. Ho: $\mu 2=\mu 3$
6. Ho: $\mu 3=\mu 4$

A grand mean of three parameters (ambient, surface, and -20 cm soil temperatures) were used in comparisons of the four stations.

3.1.4 Methods

3.1.4.1 Parameter Measurement and Data Reduction

Instrumentation specifications are detailed in Appendix A, Section 1. Data from three of the recording stations were collected on pressure sensitive strip charts housed in paper chart recorders. These recorders were multiplexed so that more than one data point was logged on each strip chart. Strip charts were collected each month (at approximately 26-28 day intervals). The chained pinyon-juniper site recorded data on a cassette tape All parameters were logged sequentially on these tapes. Data from strip charts were reduced and compiled manually, directly from the strip charts. Data collected on magnetic cassette tapes were computer "dumped," then edited and reduced from the computer printout. These latter data are also contained on nine track tapes. Data from all sources were reduced to daily means and monthly means. Standard deviation and variance were computed for both daily and monthly means. Data from spot check stations were treated in a similar manner, although no statistical computations were accomplished. The monthly mean values for all parameters are in Appendix IV-B, Tables B-1-1 through B-1-9.

3.1.4.2 Statistical Comparisons of the Four Microenvironmental Stations

A total of 65 daily averages was used from April 1975 to May 1976 for: ambient temperature ^{o}C, 1 meter above the surface, surface temperature ^{o}C, 0 meters and soil temperature ^{o}C, -20 cm and -60 cm. Sixty-five daily sums were used for precipitation measured in hundredths of inches. The data were entered into an IBM 370/168 computer and two analyses of variance tests were run. The computer furnished the level of factors, the grand mean, source of variation, the sums of squares, degrees of freedom, the mean squares, total sum of squares and the total degree of freedom (Appendix IV-B, Tables B-1-10 and B-1-11).

Two additional analyses of variance tests were performed. Monthly precipitation totals, measured in mm, from January 1975 to October 1976 were used for hypotheses testing in one analysis (Appendix IV-B, Table B-1-12). The second analysis involved mean soil moisture percent (the mean of readings taken at -20 cm, -40 cm, and -60 cm) from March 1975 to August 1976, for hypotheses testing (Appendix IV-B, Table B-1-13).

Hypothesis testing and factor interaction were tested by calculating the F ratio and comparing it with the critical F value for a one-tailed test at an alpha level of 0.05. For calculations of the F ratio refer to Appendix IV-A, Section 1.

Mean values used in the Newman-Keuls test were generated using a multiple linear regression program with the above mentioned computer. Hypotheses were tested by comparing the computed q value with the critical q value at an alpha level of 0.05. For calculations of the q value refer to Appendix IV-A, Section 1.

3.1.5 Results and Discussion

Microenvironmental data collected from continuous recording stations in the four major vegetation types on Tract C-b during 1975 and 1976 are presented below. This extended record of microenvironmental conditions, coupled with soil data analysis, is a significant contribution to the understanding of the differences in vegetation types based on the influence of biotic factors.

General descriptions of the microenvironment of each vegetation type studied (chained pinyon-juniper rangeland--CPJR, pinyon-juniper woodland--PJWD, upland sagebrush--UPSB, and bottomland sagebrush--BLSB) are presented. Comparisons between vegetation types based on microenvironment are also made and correlated with significant species distributions and herbaceous standing crop information. Microenvironmental factor interactions are also discussed.

3.1.5.1 Microenvironmental Characteristics of Tract C-b

3.1.5.1.1 General

The four major vegetation types on Tract C-b (see Vegetation, Vol. IV, Section 3) are structurally or physiognomically distinct. This is a characteristic related to species composition of these communities, although the vegetation has regional continuity in terms of major species. Structurally, in terms of height characteristics of vegetation, the major types range from woodlands (pinyon-juniper woodlands, ca. 6 to 10 m) to tall shrublands (chained pinyon-juniper rangelands and bottomland sagebrush, ca. 1 to 3 m) to low shrublands (upland sagebrush, ca. 0.5 m). From an aerial aspect, the canopy characteristics of these types can be similarly ordered. The canopy of the woodlands tends to be the more closed, while the shrubland canopy is more open, followed by a pronounced lack of a distinct canopy in the low shrublands.

The structural characteristics of the vegetation types have bearing on the microenvironment in the manner in which the plants buffer the effects of climate outside the boundary layer (i.e., the uppermost level of vegetation). This relates to the blocking of solar radiation, the interception of precipitation, and the buffering of winds. Inside the boundary layer, plant density and vertical layering of plants growing at different heights influenced the microenvironment. The effects here are on temperature stratification and moisture interception, with secondary influences on wind and insolation. The results are controls on evaporation, light, and soil moisture.

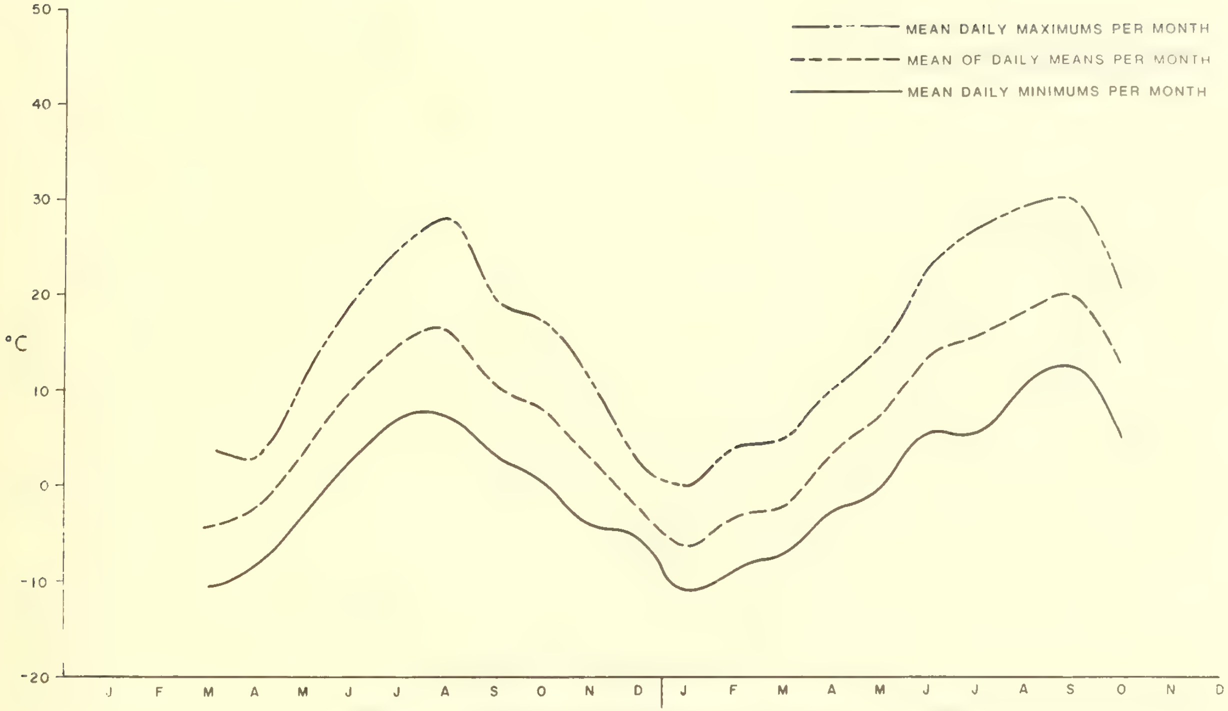
The most significant effects which the vegetation structure has on microenvironmental conditions on Tract C-b are those relating to the water budget. Incident radiation or solar insolation appears to be the most important driving variable, but this interrelates with temperature distributions, such as vertical mixing, as well as evaporative loss. Soil type has some influence on moisture available from the soil, but this is secondary since leaching is very limited in all soils. Interception of precipitation by vegetation has a secondary influence on soil moisture. The overall effect is the predominant microenvironmental interface between temperature and moisture, controlled by surface insolation through the effect of canopy cover and vertical stratification of vegetation. The following discussion of temperature and moisture conditions on the Tract and of the microenvironmental conditions of each of the four major vegetation types will illustrate this system of controls and how it delineates vegetation types.

3.1.5.1.2 Temperature

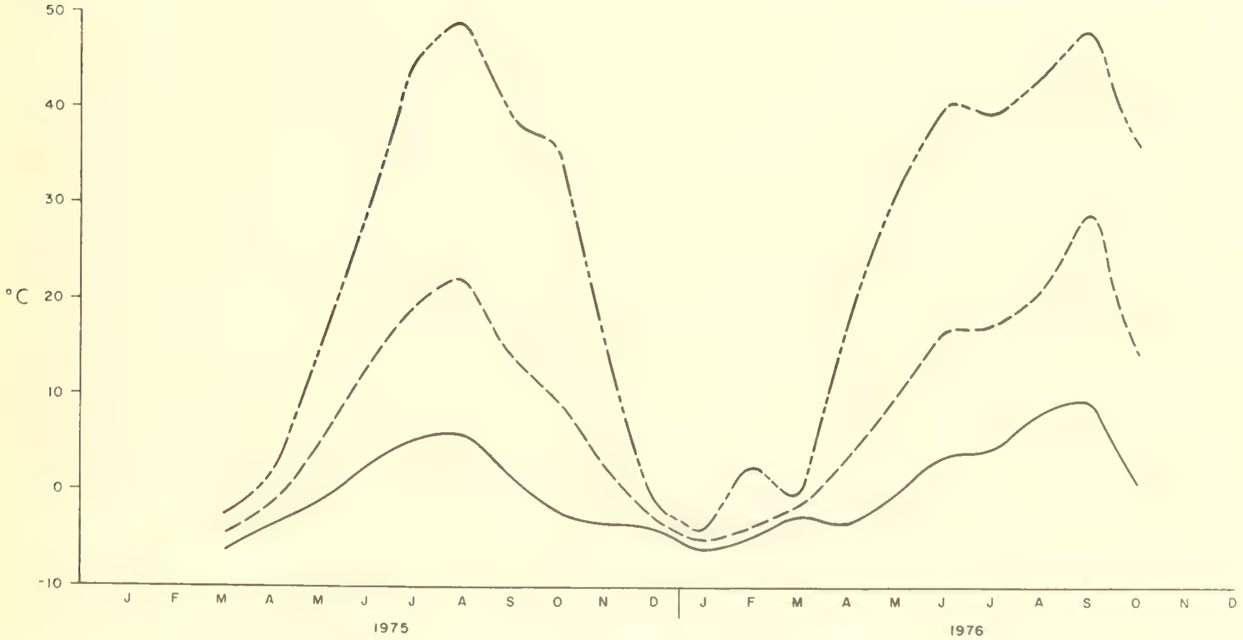
Mean minimum and mean maximum temperatures recorded at the ground surface in the four major vegetation types show a general pattern of warming beginning in April and ending in September. Highest mean minimum temperatures were recorded in August and September (44° to 49°C), lowest mean minimum temperatures were recorded in January and February (-1° to -7°C) (Figures 3-1-2 through 3-1-5).

The importance of minimal temperatures relates to the availability of soil water and to the resumption of plant growth. Soil water becomes available at 0°C, although extensive root elongation begins at 18 to 20°C. Plant growth and soil bacterial action resume around 4°C. Soil bacterial action is at optimal conditions at 30°C, while plant root growth is optimal at 40°C (Brady 1974). Germination of seed plants resumes at from 7 to 10°C (Brady 1974). The mean minimum temperatures recorded in the four major vegetation types indicate significant differences in the initiation and duration of site-specific growing seasons (Figures 3-1-6 and 3-1-7).

Upland sagebrush sites are the first to reach sustained surface temperatures above 0°C (Figures 3-1-6 and 3-1-7). Mean minimum temperatures at the surface in this type remained above freezing from April until November in 1975, and May to September in 1976. Chained rangeland sites (Figures 3-1-3, 3-1-6, and 3-1-7) exceeded the freezing point in May and fell below freezing in September of 1975 and 1976. Pinyon-juniper woodland sites reached sustained mean minimum temperatures above freezing in May of 1975 and 1976 (Figures 3-1-2, 3-1-6, and 3-1-7), and mean minimum temperatures at the surface in the woodlands dropped below freezing in September of 1975 and 1976. Bottomland sagebrush communities reached a sustained mean minimum temperature rise above

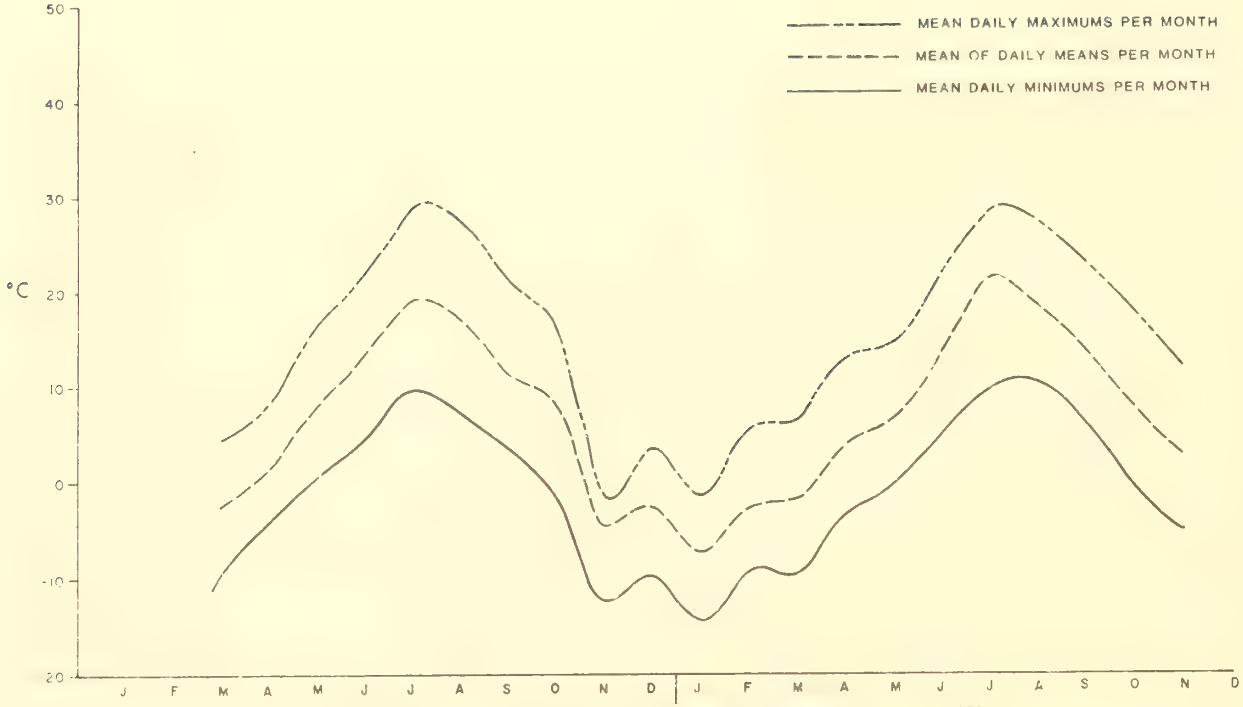


AMBIENT TEMPERATURE AT 1 METER

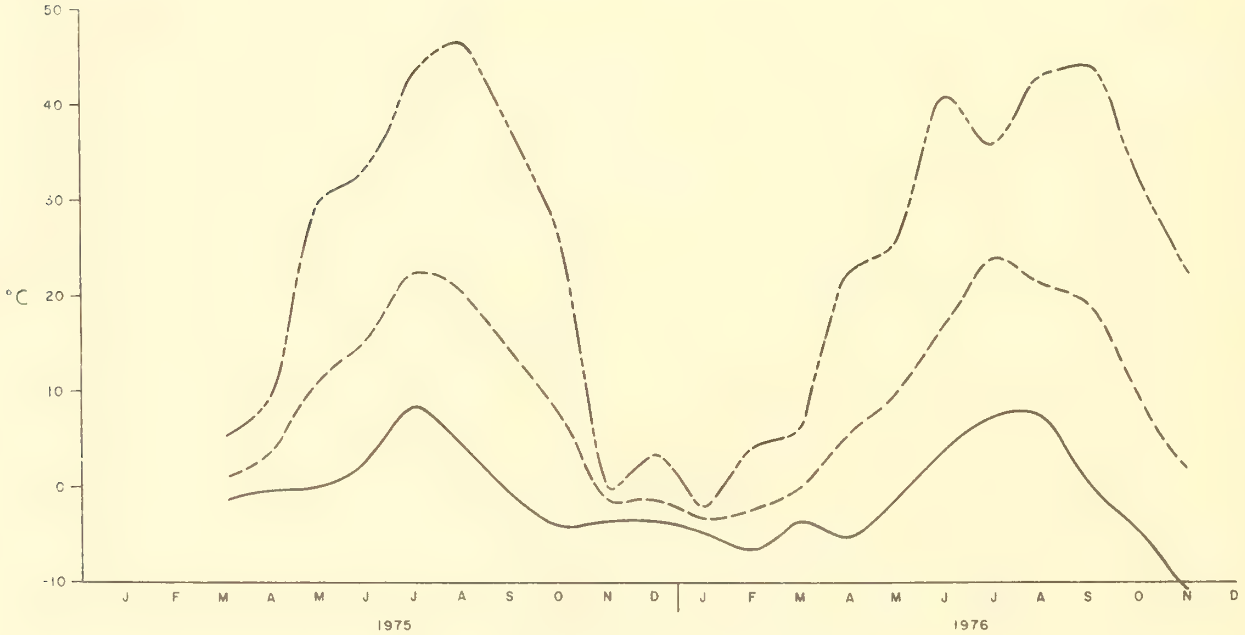


SURFACE TEMPERATURE AT 0 METERS

FIGURE 3-1-2 TEMPERATURE SUMMARY
PINYON-JUNIPER WOODLAND (PJWD)
1975 AND 1976, TRACT C-b

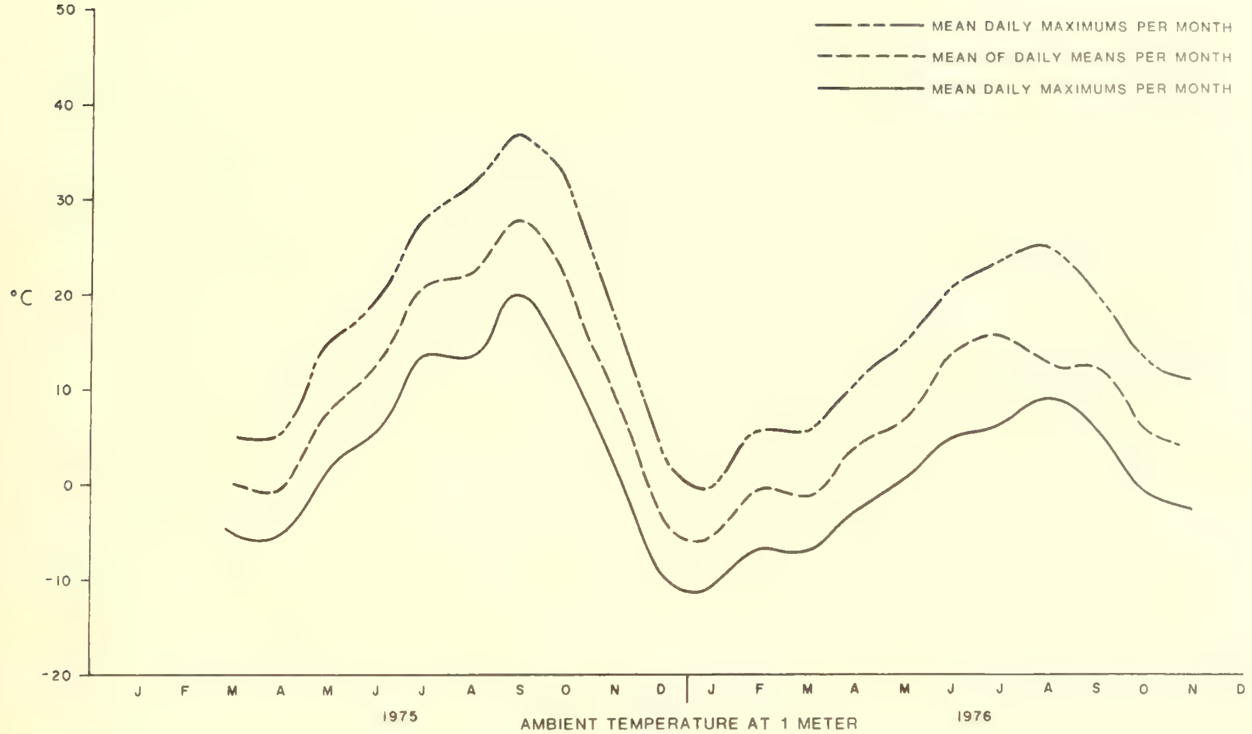


AMBIENT TEMPERATURE AT 1 METER

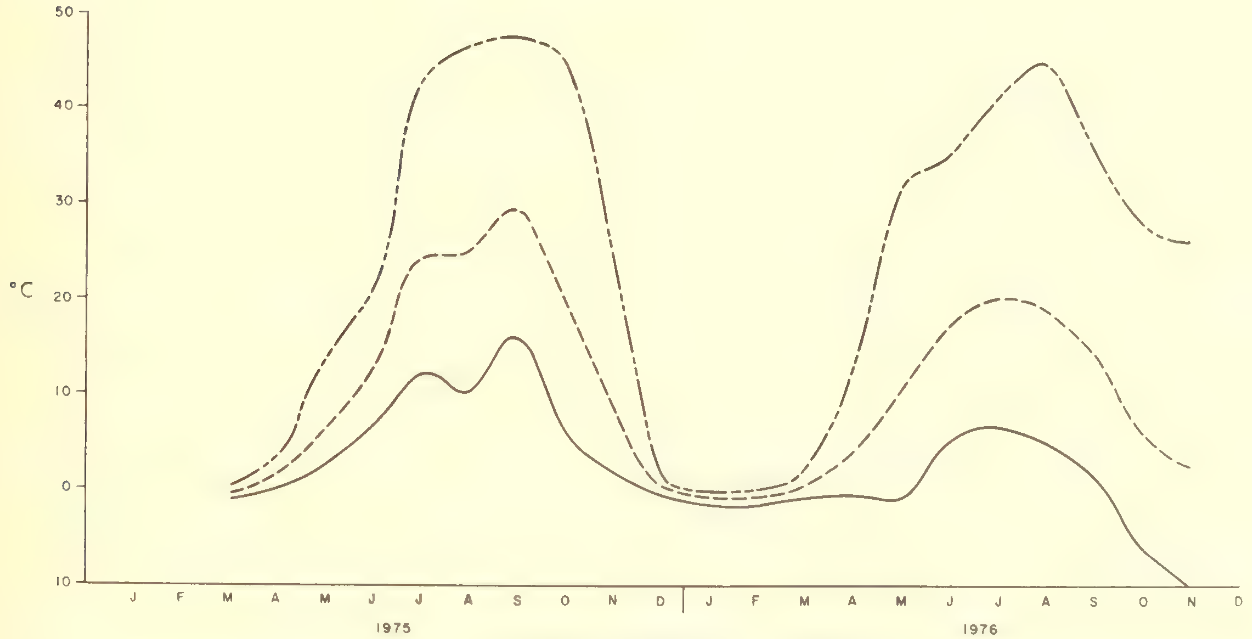


SURFACE TEMPERATURE AT 0 METERS

FIGURE 3-1-3 TEMPERATURE SUMMARY
CHAINED PINYON-JUNIPER RANGELAND (CPJR)
1975 AND 1976, TRACT C-b

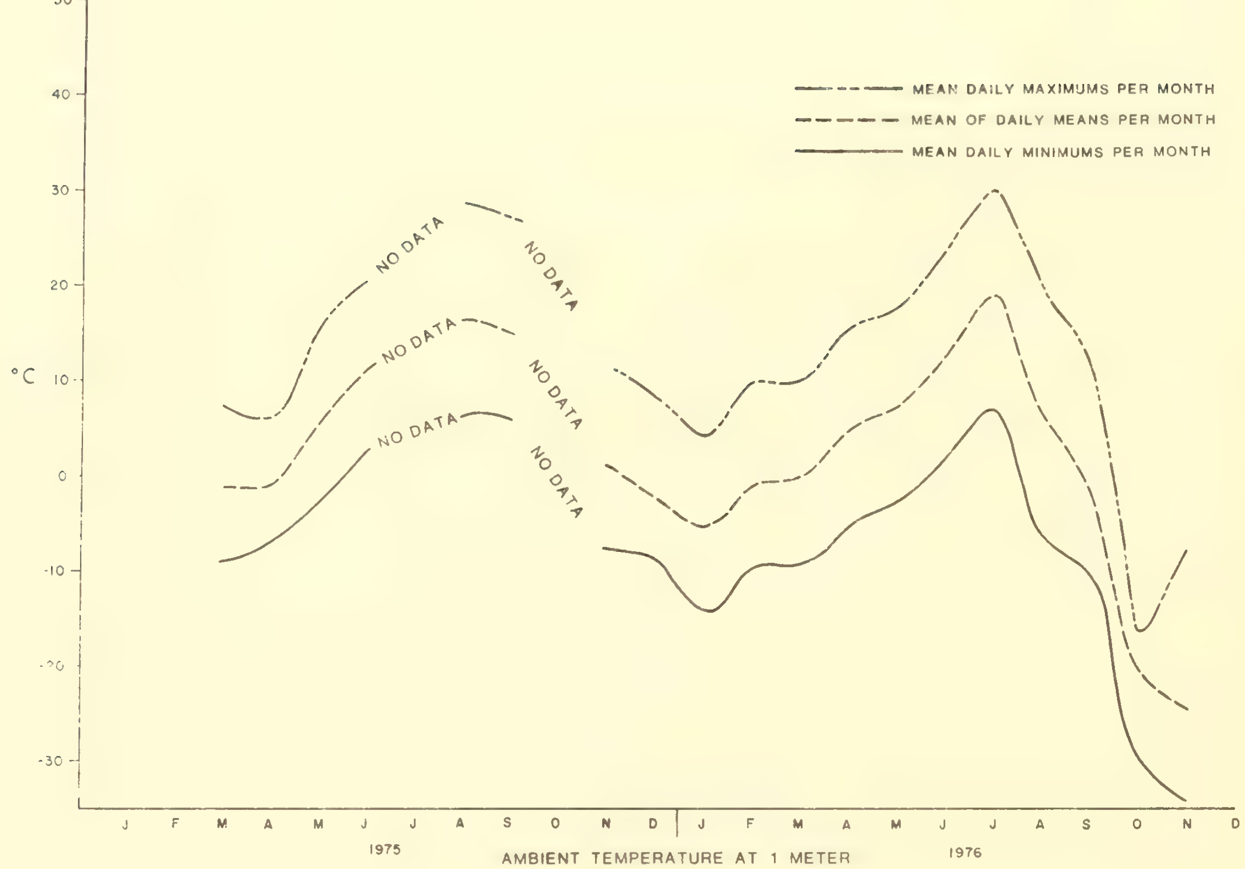


AMBIENT TEMPERATURE AT 1 METER

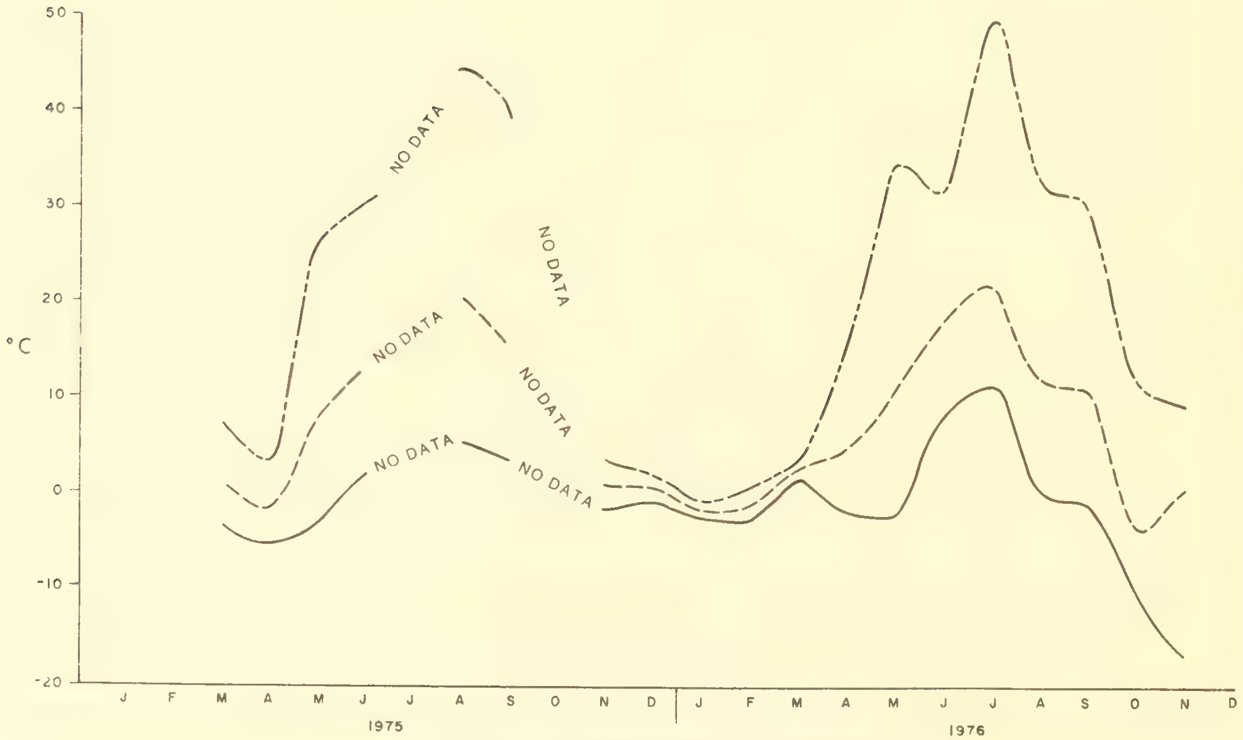


SURFACE TEMPERATURE AT 0 METERS

FIGURE 3-1-4 TEMPERATURE SUMMARY
UPLAND SAGEBRUSH (UPSB)
1975 AND 1976, TRACT C-b

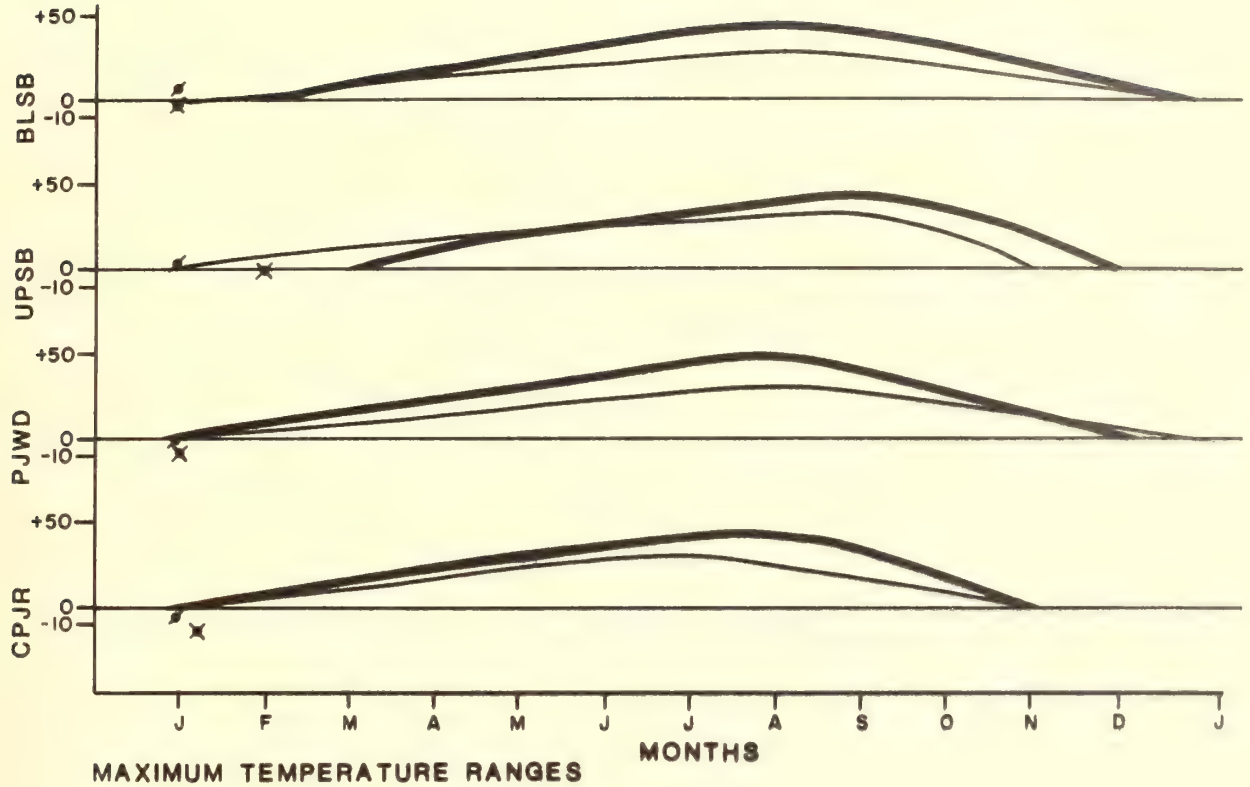


AMBIENT TEMPERATURE AT 1 METER

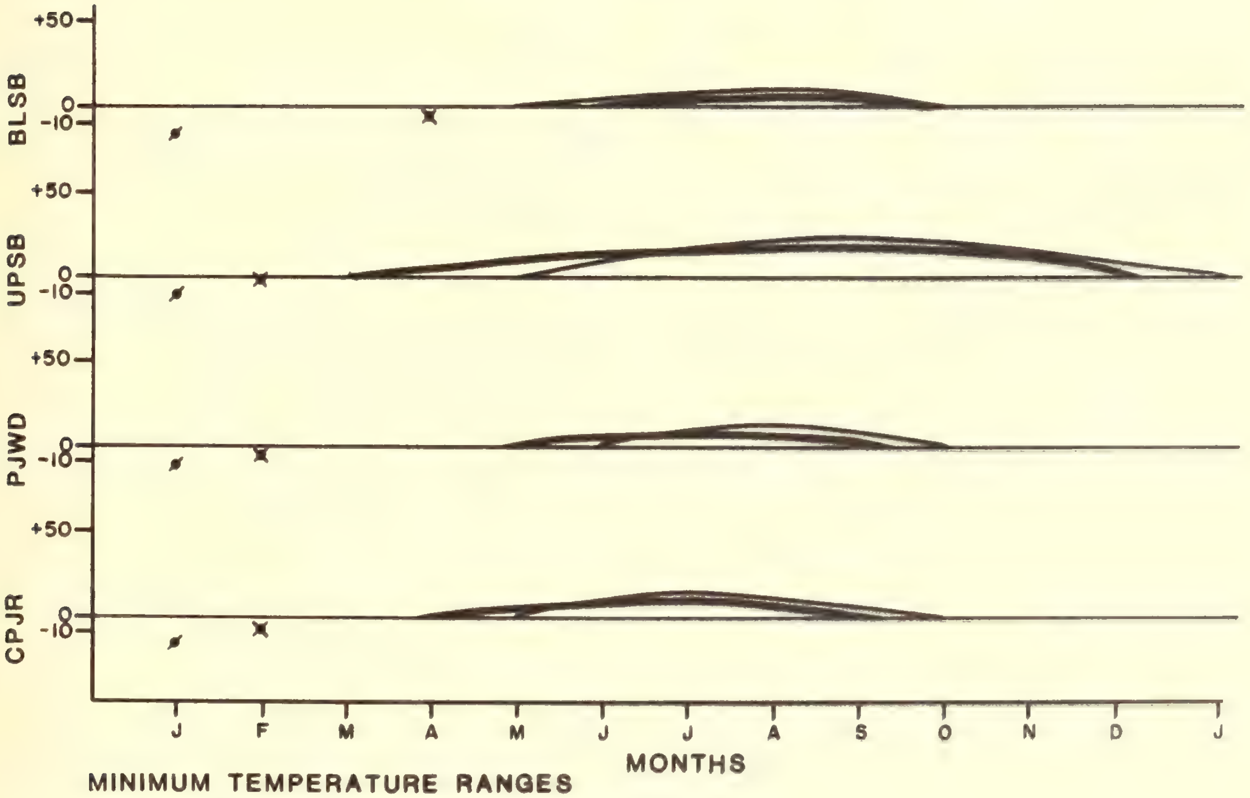


SURFACE TEMPERATURE AT 0 METERS

FIGURE 3-1-5 TEMPERATURE SUMMARY
BOTTOMLAND SAGEBRUSH (BLSB)
1975 AND 1976, TRACT C-b



MAXIMUM TEMPERATURE RANGES



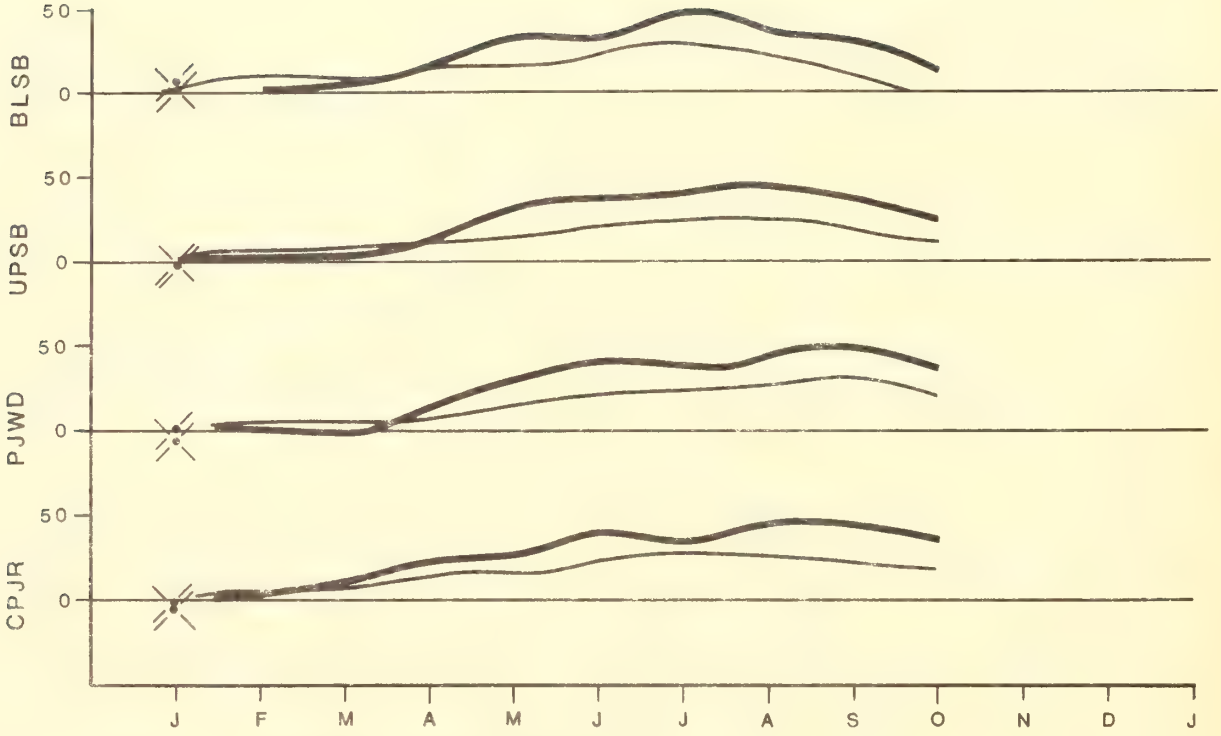
MINIMUM TEMPERATURE RANGES

HEAVY LINES ARE SURFACE TEMPERATURE RANGES

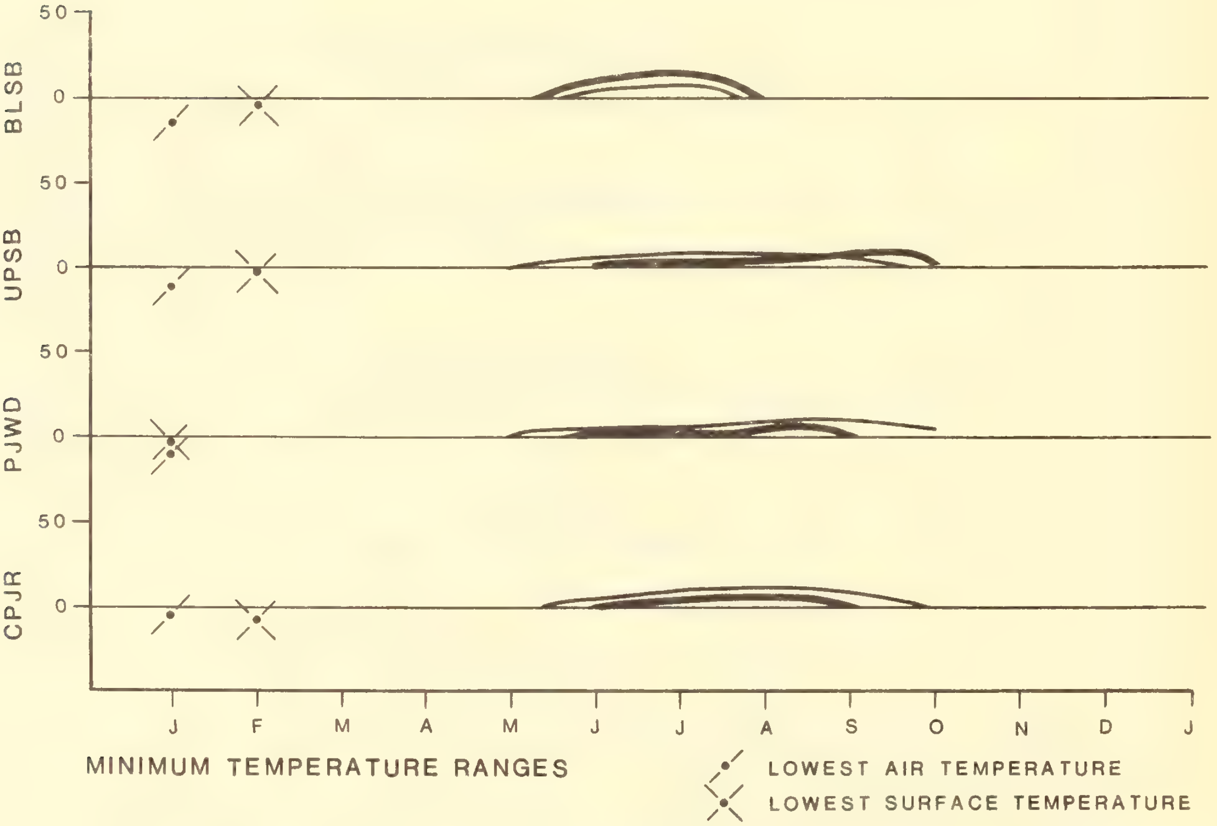
ø LOWEST AIR TEMPERATURE

✖ LOWEST SURFACE TEMPERATURE

FIGURE 3-1-6 MINIMUM AND MAXIMUM TEMPERATURE RANGES FROM SURFACE AND FREE AIR SENSORS, 1975



MAXIMUM TEMPERATURE RANGES



MINIMUM TEMPERATURE RANGES

FIGURE 3-1-7 MINIMUM AND MAXIMUM TEMPERATURE RANGES FROM SURFACE AND FREE AIR SENSORS OF 1976

freezing later in the season than did other habitat types (Figures 3-1-5, 3-1-6, and 3-1-7). Mean minimum temperatures in these sites exceeded 0°C in late May and early June and fell below freezing in October of 1975 and August of 1976. Frost dates for spring and fall of 1975 and 1976 are given in Table 3-1-2.

The effective insolation appears to be the driving force responsible for the difference in growing season between community types. Insolation effects are related directly to the height and density of the shrub canopy, which determine the amount of effective insolation reaching the surface and the vertical mixing of air between the canopy and the surface. The amount of insolation received at the surface also relates to soil temperatures and soil water availability. The low stature of the shrub layer in the upland sagebrush sites allows direct surface heating by incoming solar radiation. The fine textured nature of the soils in these sites adds to the heat storage capacity as well. The tendency for these soils to be moist in early spring should produce lower temperatures since moist soils warm more slowly than dry soils (Brady 1974). This effect is apparently counteracted by the high insolation and low impedence of heat transfer from air to soil resulting from the low vegetation canopy height. Once these higher soil temperatures are attained, the soil water content would act to retard diurnal temperature variations in the soil. The overall effect produced is more rapid heating coupled with sustained soil and surface temperatures. This warming would occur even in the presence of a shallow snow pack (Geiger 1975).

The effective insolation at the surface in chained rangeland sites is reduced in comparison to that in the upland sagebrush as a result of the greater shrub canopy height, more open soil areas, and poorer vertical mixing allowing lesser transfer of heat from air to soil. Vertical mixing effects on heat conduction from air to soil may be further retarded because of slash. The piles of slash left by chaining act to reduce the total effective surface insolation and may allow portions of the surface (i.e., those adjacent to the slash) to remain relatively cool. The cooler areas would cause an increase in lateral conduction of heat away from areas receiving more insolation, thus causing a decrease in overall temperature. The less dense herb layer of the chained rangelands tends to lose heat more rapidly than the more continuous herb cover of the upland sites. The overall effect is a greater dependence on increasing air temperatures in order for the surface to reach sustained minimum temperatures above freezing. This may well account for the difference in warming between the chained sites and the upland sagebrush sites.

The influence of canopy cover in reducing effective insolation to the surface is increased in the pinyon-juniper woodlands by the tree crown. Vertical mixing between air and soil is accordingly reduced. This feature is increased by the presence of late-lying snow and by diurnal temperature variations.

Table 3-1-2

OCCURRENCE OF FROSTS IN THE FOUR MAJOR VEGETATION TYPES, 1975-76
TRACT C-b

	1M Level		Surface Level		
Vegetation Type	1975	1976	1975	1976	
Pinyon-Juniper Woodland	6/26	6/13	6/26	5/28	SPRING
	9/16	-	9/15	-	FALL
Chained Pinyon-Juniper Rangeland	4/30	6/15	6/6	4/29	SPRING
	9/21	-	9/20	-	FALL
Bottomland Sagebrush	6/11	5/2	6/11	5/5	SPRING
	8/30	9/16	8/30	10/20	FALL
Upland Sagebrush	5/9	6/13	4/17	5/1	SPRING
	10/21	10/26	12/18	10/26	FALL

Bottomland sagebrush sites receive lesser amounts of effective insolation at the surface for the same reasons. In these sites the relatively closed nature of the shrub canopy is even more effective in retarding the amount of heat received at the surface than at other sites. Transfer of heat between air and soil within the canopy is reduced accordingly. These factors produce a situation in which even greater sustained warming of the air is needed to raise the temperature of the surface. The sustained warming of the air is also complicated by cold air drainage, which occurs regularly in the bottomland sites. Warm surface temperatures continue into the latter part of the growing season as a result of the reversal of this same mechanism. The shrub canopy effectively blocks radiation of heat from the soil surface once the soil is thoroughly warmed. Soil depth and fine texture add to the sustained warming.

Ambient air temperatures (recorded at 1 M, Figures 3-1-2 through 3-1-5) are somewhat out of phase with surface temperatures, as expected. Air temperature mean minima (Figures 3-1-6 and 3-1-7) lag behind the surface temperatures in sustaining above freezing levels. This lag is primarily because of advection.

Although surface and air temperatures are related in this manner, surface temperatures are more important relative to plant functions. Typically, the temperature of leaf tissue lies somewhere between the air temperature and the surface temperature. The drier and warmer the conditions, the closer the leaf temperature is to surface temperature (Geiger 1975).

Maximum temperatures may also be indicators of plant stress in an arid or semi-arid climate. The major importance of maxima is their relationship to evapotranspiration. Whereas neither the surface temperature nor free air minimum temperatures appear to be limiting to vegetation during the growing season (aside from the unseasonable frosts occurring in June of 1976, Table 3-1-2), mean maximum temperatures may have important effects. During the growing season, mean maximum temperatures, both at the surface and in free air, are typically high (38-40°C) (Table 3-1-3). Highest mean maximum temperatures (Figures 3-1-2 through 3-1-5) occur from July through September when soil moisture is lowest (Figure 3-1-8). Mean maximum temperatures at the soil surface during late summer can reach as high as 49°C, while free air mean maximum temperatures are somewhat lower at about 30°C. The potential for increased evaporation from the soil surface and increased transpiration from vegetation during this period is significant. Of equal significance are the increased plant requirements for water and nutrient uptake to accomplish seed production and maturity. The effects of decreasing soil moisture are accompanied by decreasing soil water availability (resulting from increasing soil tension--Table 3-1-2). This is of particular importance in soils with higher clay content because these soils hold more moisture hygroscopically and therefore unavailable to plants (see below).

Table 3-1-3

GROWING SEASON TEMPERATURE MAXIMA AND MINIMA, 1975-76 (^{o}C)

		1975		1976	
Vegetation Type		Air	Surface	Air	Surface
Pinyon-Juniper Woodland	Mean Min.	Jun 2.5	Jun 2.8	Jul 5.0	Jun 3.7
	Mean Max.	Aug 27.5	Aug 49.0	Jul 28.0	Sep 48.1
Chained Pinyon-Juniper Rangeland	Mean Min.	Jun 4.4	Jun 2.6	Jun 4.7	Jan 5.8
	Mean Max.	Jul 29.0	Aug 46.5	Jul 28.5	Sep 43.5
				Jun 1.6	Jun 8.0
Bottomland Sagebrush	Mean Min.	Jun 2.8	Jun 2.0	Aug -7.1	Aug -0.2
	Mean Max.	Aug 28.2	Aug 44.1	Jul 29.7	Jul. 49.1
Upland Sagebrush	Mean Min.	Jun 5.0	Jun 6.8	Jun 4.8	Aug 5.0
	Mean Max.	Sep. 36.8	Sep 47.3	Aug 24.5	Aug 44.8

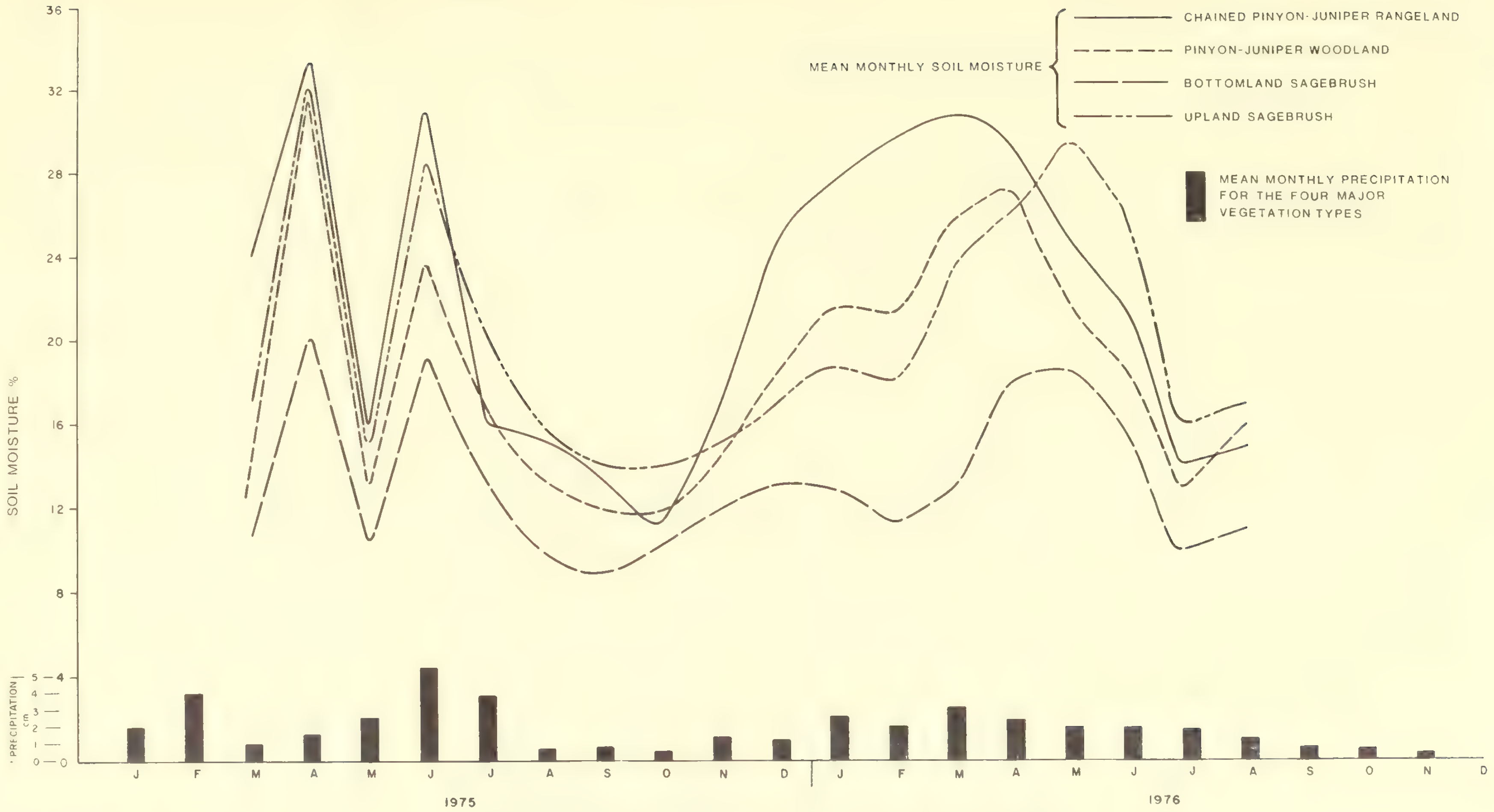


FIGURE 3-1-8 MONTHLY SOIL MOISTURE PER VEGETATION TYPE
PLOTTED AGAINST MEAN MONTHLY PRECIPITATION
FOR THE FOUR MAJOR VEGETATION TYPES

3.1.5.1.3 Moisture

3.1.5.1.3.1 Precipitation

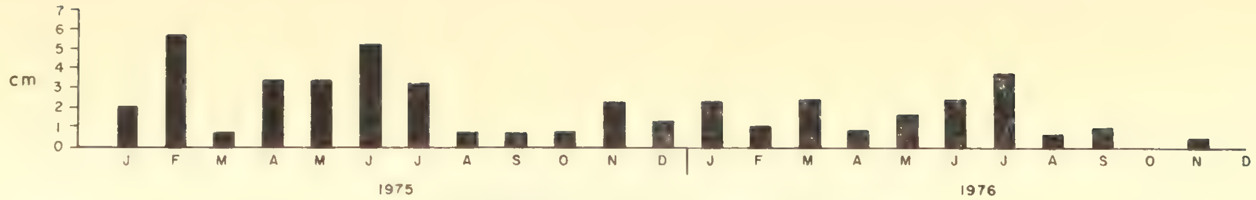
Precipitation measured at 20 cm above the ground surface in the four major vegetation types is summarized in Figure 3-1-9.

Precipitation during 1975 was lowest in the summer months (June-August), averaging 29 mm per month. Winter precipitation (December-February) averaged 31 mm per month, spring precipitation averaged 17 mm per month (March-May). The lowest precipitation period was fall (September-November) with an average of 9 mm of moisture. Precipitation in these same periods during 1976 was 13 mm (June-August), 21 mm (December-February), 24 mm (March-May) and 7 mm (September-November).

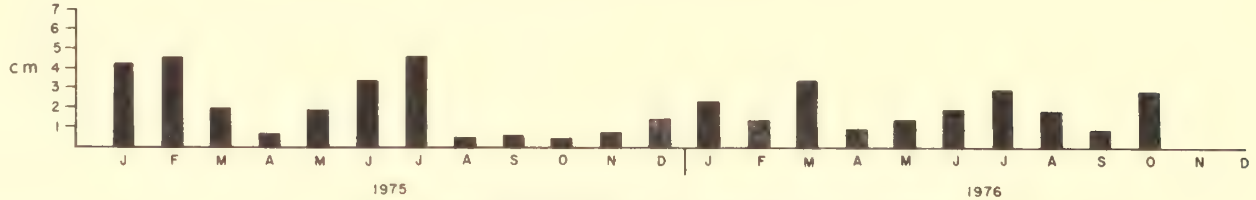
The periods of most significant moisture accumulation in all of the major vegetation types are May-June and January-March. The late spring, early summer precipitation is significant to the resumption of plant growth, while the winter precipitation contributes to the increased soil moisture regime in early spring. The occurrence of early spring snows (March-April) is of great importance. These snows typically have a high moisture content (Figure 3-1-10). Runoff resulting from this moisture is minimal, and moisture is supplied over a longer period of time than would be available from an equal amount of water falling from rain during summer thunderstorms.

Average precipitation for this region as reported by Bradley (1976) for the years 1941-1970 is 280 mm (summer, 76 mm; fall, 51 mm; winter, 102 mm; spring, 51 mm). A marked difference occurred in precipitation between the years of 1975 and 1976 (Table 3-1-4). Total precipitation in 1975 was not only greater than in 1976, but was accumulated during different months. Precipitation in 1975 occurred during growing season months (March-September), predominantly in early summer. During this same period in 1976, precipitation was greatest in early spring while summer precipitation was significantly low (Figure 3-1-11). This difference in moisture on Tract C-b is related to the lower herbaceous standing crop values obtained in 1976 as compared with 1975 (Vegetation, Section 3).

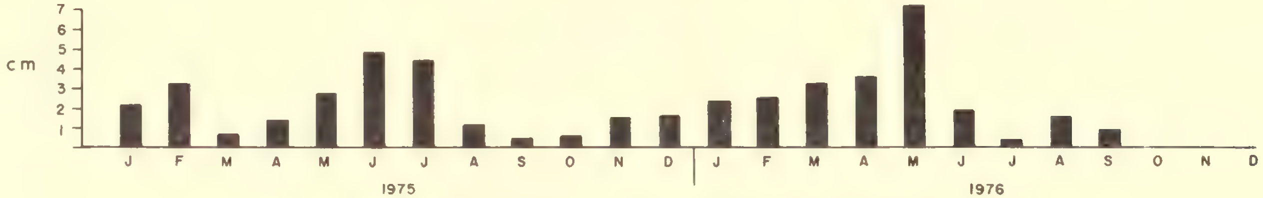
The precipitation differences between vegetation types and between years do not appear to be related to long term trends. The differences in accumulated moisture may be the result of vegetation structure. The high precipitation received by woodlands is the probable result of the interception of summer rains (Tueller and Clark 1975); 1975 precipitation was predominantly in this form. Precipitation in 1976 was, conversely, received as early spring snows which tend to accumulate in upland sagebrush sites. These sites receive additional snow as the result of fallout produced by the slowing effect of the forest canopy. Winds tend to eddy at the forest edges, thereby dropping a significant amount of their snow load (Costin et al. 1961).



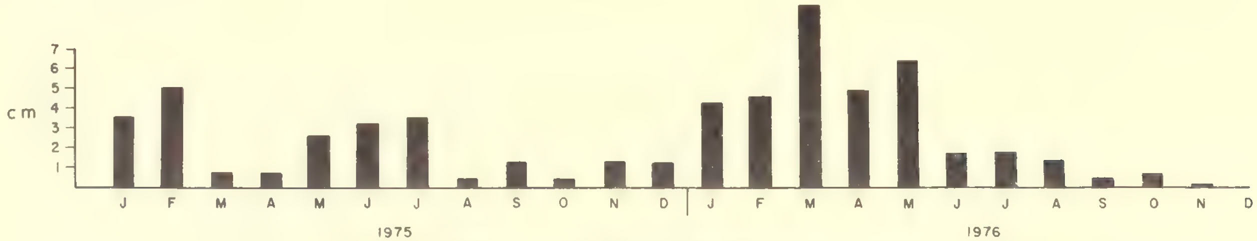
PRECIPITATION - TOTAL ACCUMULATION PER MONTH
PINYON JUNIPER WOODLAND (PJWD)



PRECIPITATION - TOTAL ACCUMULATION PER MONTH
CHAINED PINYON - JUNIPER RANGELAND (CPJR)



PRECIPITATION - TOTAL ACCUMULATION PER MONTH
BOTTOMLAND SAGEBRUSH (BLSB)



PRECIPITATION - TOTAL ACCUMULATION PER MONTH
UPLAND SAGEBRUSH (UPSB)

FIGURE 3-1-9 PRECIPITATION SUMMARY FOR THE FOUR MAJOR VEGETATION TYPES, 1975 AND 1976, TRACT C-b

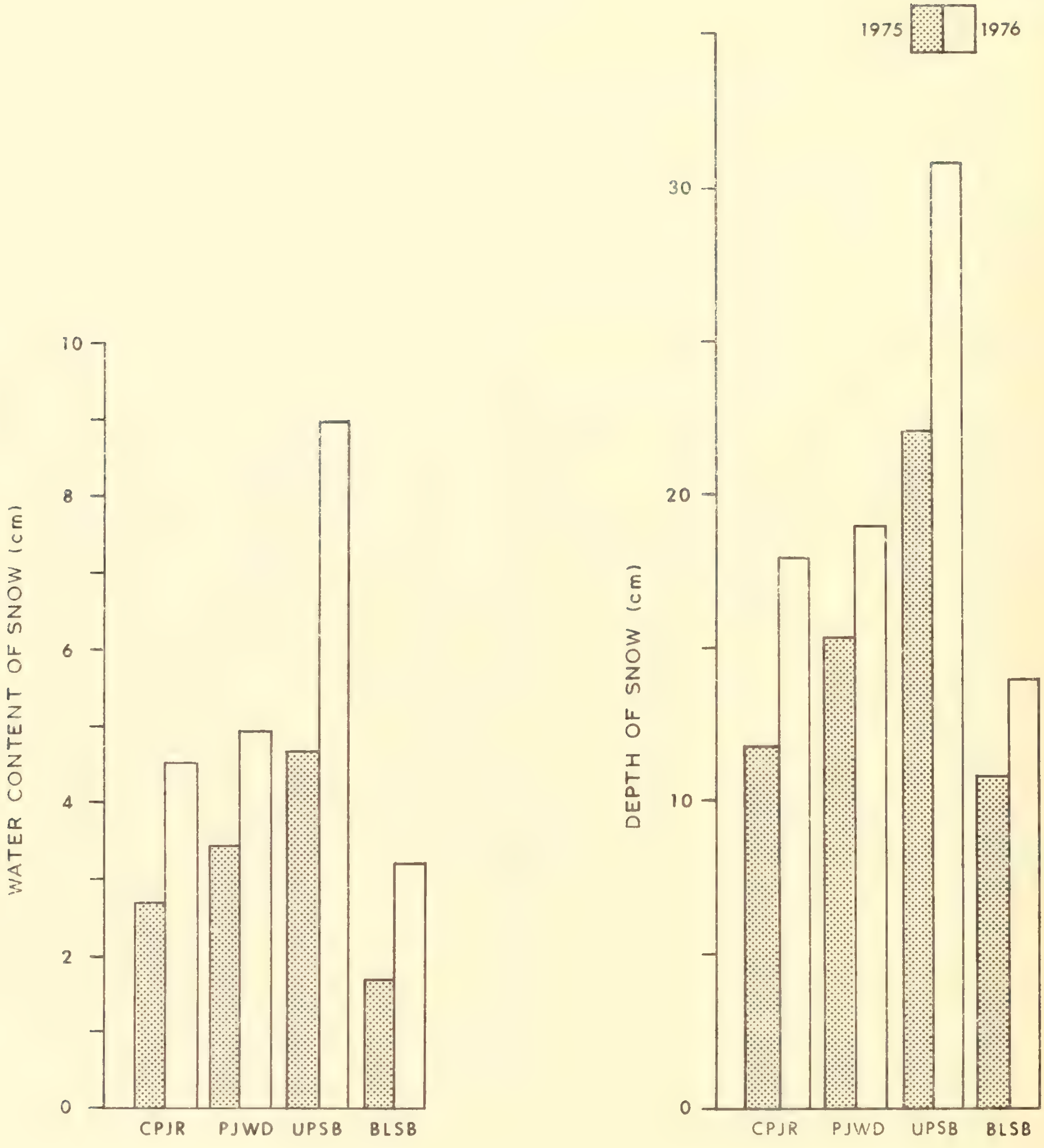


Figure 3-1-10 COMPARISON OF WATER CONTENT OF SNOW AND SNOW DEPTH IN FOUR VEGETATION TYPES IN WINTERS OF 1974-75 AND 1975-76.

Table 3-1-4

PRECIPITATION (mm) TOTALS (DEC-SEPT)
FOR THE FOUR MAJOR VEGETATION TYPES, 1975-76
TRACT C-b

	Pinyon-Juniper Woodland	Chained Pinyon-Juniper Rangeland	Bottomland Sagebrush	Upland Sagebrush
1975	246	235	215	235
1976	162	170	181	216

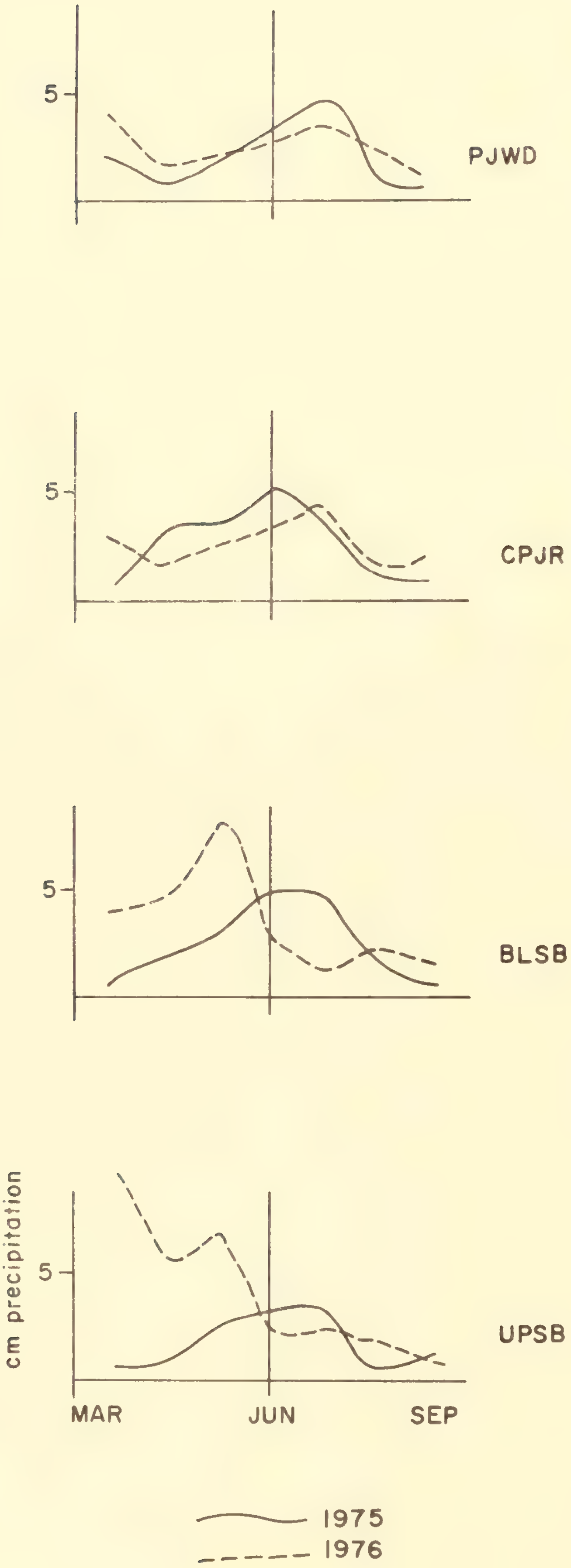
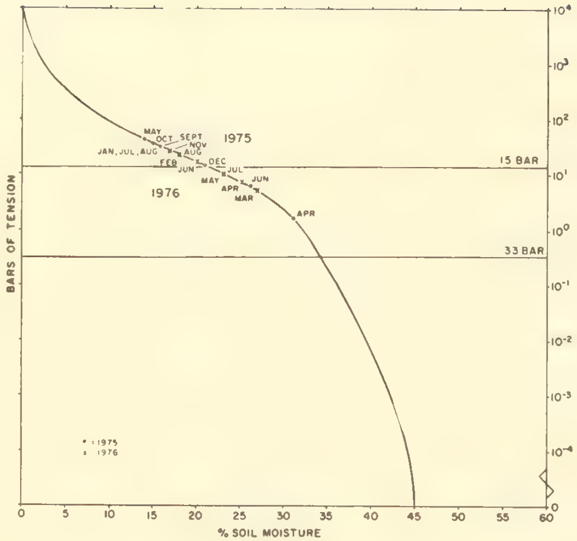


FIGURE 3-1-11
COMPARISON OF
PRECIPITATION
IN 1975 AND 1976
FOR THE
FOUR MAJOR
VEGETATION
TYPES, TRACT C-b

3.1.5.1.3.2 Soil Moisture

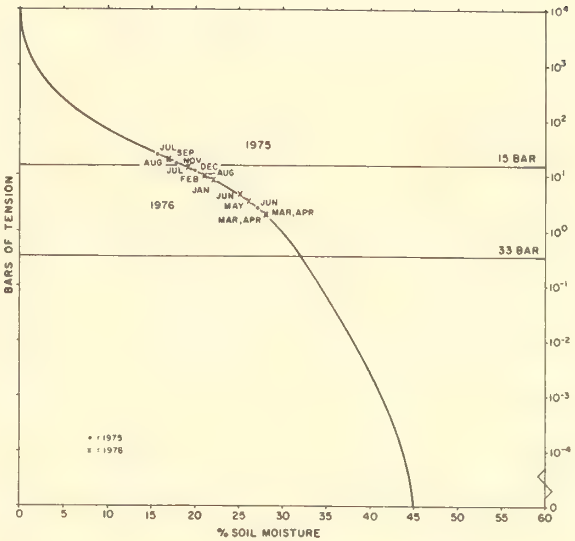
In a semi-arid region, such as the Piceance Basin, the importance of the precipitation regime is modified into terms of moisture available to plants. Some moisture as precipitation is intercepted by vegetation or immediately used from the soil before it can enter horizons where it is stored. However, the moisture available from soil recharge and storage is highly significant. This is particularly true for all vegetation during mid-summer, and for trees and other deep rooted plants at other seasons as well. In this latter category, winter and early spring moisture is very critical. This is moisture available from deeper within the soil (i.e., the soil moisture control section mentioned above), and therefore, less available to evaporation. Since soil moisture is a function of soil type as well as vegetation, soil moisture curves (sometimes called desorption curves) have been drawn for each of the four major vegetation types (Figure 3-1-12 a-d). These curves are constructed by plotting hygroscopic coefficient, permanent wilting coefficient, field capacity, and the saturation capacity for each soil on a semi-logarithmic scale against soil moisture. Monthly soil moisture values can then be plotted directly on this curve. The soil tension for each month where data for soil moisture are available can then be approximately derived. This information is useful in determining trends in soil moisture availability between years (refer to Volume V) and in defining differences in vegetation type. This critical point of possible difference between vegetation types is applicable to management practices, especially revegetation and related activities, such as soil removal, stockpiling, and other soil treatments.

Soil water is commonly assumed to be available to plants at soil tensions between -15 bar (permanent wilting coefficient) and -1/3 bar (field capacity) (Brady 1974). In theory plants are unable to absorb soil water at tensions below -15 bar. However, these concepts of internal plant pressures were developed for agricultural species and do not appear to apply to native vegetation, particularly in semi-arid and desert areas. Studies to determine water potentials of semi-arid species, desert plants, and halophytic plants indicate that many shrub species maintain internal pressures significantly below the -15 bar level. A number of these studies have been conducted in the Intermountain region and report results which are applicable to the environmental conditions and to shrub species found on Tract C-b. Dina et al. (1973) show seasonal minimum water potentials of -70 bar for big sagebrush and -46 bar for bitterbrush and Gambel's oak. Branson et al. (1976) show seasonal maximum average internal plant stresses of -117 bar (p. 1110) for Nuttall's saltbush; corresponding maximum soil moisture tensions are reported by Branson to reach an average value of -85 bar. This same research reports maximum tensions for big sagebrush at >-60 bar; greasewood at >-60 bar; rabbitbrush at ≥-40 bar, and winter fat at ≥-90 bar. The mean internal plant stress values reported in this study all exceed -30 bar. These reported values indicate that the major shrub



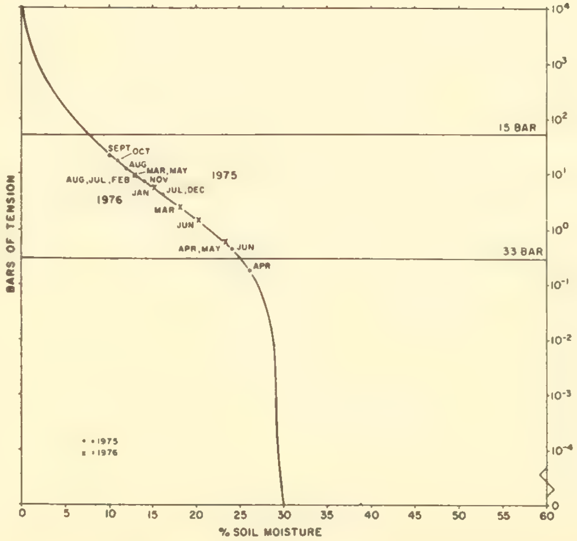
	PRESSURE IN BARS	
1975	MAR	–
	APR	1.50
	MAY	40.00
	JUN	6.00
	JUL	10.00
	AUG	20.00
	SEPT	30.00
	OCT	35.00
	NOV	25.00
	DEC	15.00
1976	JAN	25.00
	FEB	20.00
	MAR	5.00
	APR	7.00
	MAY	10.00
	JUN	17.00
	JUL	25.00
	AUG	25.00
	SEPT	
	OCT	
	NOV	
	DEC	

(a)
PINYON-JUNIPER WOODLAND (PJWD) 1975-1976



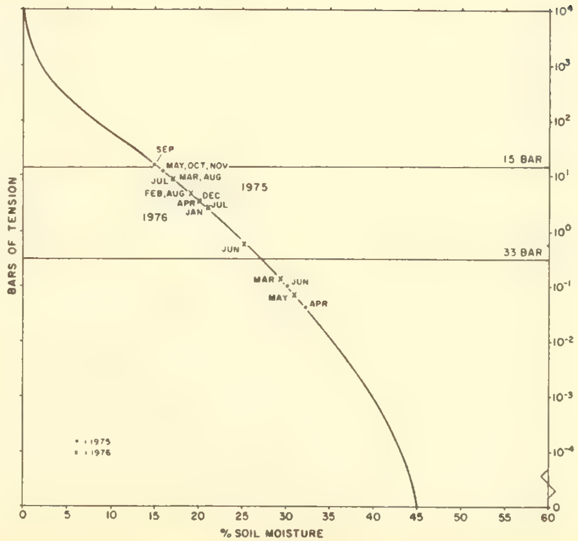
	PRESSURE IN BARS	
1975	MAR	2.00
	APR	2.00
	MAY	–
	JUN	2.50
	JUL	25.00
	AUG	10.00
	SEPT	20.00
	OCT	–
	NOV	5.00
	DEC	12.00
1976	JAN	9.00
	FEB	10.00
	MAR	2.00
	APR	2.00
	MAY	3.50
	JUN	4.50
	JUL	7.00
	AUG	20.00
	SEPT	
	OCT	
	NOV	
	DEC	

(b)
CHAINED PINYON-JUNIPER RANGELAND (CPJR) 1975-1976



	PRESSURE IN BARS	
1975	MAR	10.00
	APR	0.20
	MAY	10.00
	JUN	0.40
	JUL	4.00
	AUG	12.00
	SEPT	20.00
	OCT	17.00
	NOV	7.00
	DEC	4.00
1976	JAN	5.50
	FEB	10.00
	MAR	2.50
	APR	0.60
	MAY	0.60
	JUN	1.50
	JUL	10.00
	AUG	12.00
	SEPT	
	OCT	
	NOV	
	DEC	

(c)
BOTTOMLAND SAGEBRUSH (BLSB) 1975-1976



	PRESSURE IN BARS	
1975	MAR	8.00
	APR	0.04
	MAY	13.00
	JUN	0.10
	JUL	2.50
	AUG	8.00
	SEPT	16.00
	OCT	13.00
	NOV	13.00
	DEC	3.50
1976	JAN	2.50
	FEB	4.50
	MAR	0.15
	APR	3.50
	MAY	0.07
	JUN	0.60
	JUL	8.00
	AUG	4.50
	SEPT	
	OCT	
	NOV	
	DEC	

(d)
UPLAND SAGEBRUSH (UPSB) 1975-1976

FIGURE 2.1-12 SOIL MOISTURE CURVES FOR THE FOUR MAJOR VEGETATION TYPES, TRACT C-species found on Tract C-b are adapted to the extremes of soil tension values derived from actual soil moisture measurements and soil desorption curves. The growing season soil water tension on Tract C-b is figured at -25 bar for shrub dominated stands containing many of the species mentioned above. Little definitive work has been done to determine internal stresses for pinyon pine and juniper, but it is apparent that the seasonal water potential low of -40 calculated for the Tract is within the tolerance of mature individuals of these species.

From the soil moisture curves it can be seen that woodlands experience the greatest soil moisture stress, reaching -25 bars of pressure in summer (See also Table 3-1-5). Chained rangelands also experience levels of soil moisture tension, which are limiting (>-15 bars) by mid to late summer. Soil moisture availability in bottomland and upland sagebrush sites does not become limiting until late summer or early fall. In upland sagebrush sites, however, evaporation appears to affect otherwise high soil moisture availability in a negative manner. This effect is discussed more fully below. Woodlands are also subjected to high evaporation rates (when correlated with soil water availability). This effect compounds the soil water stresses in those sites.

The interrelationships between high temperature, soil moisture, available water capacity of soil, and evaporation are of great importance. Results of available water capacity determinations for soils in the four major community types (Table 3-1-5, Figure 3-1-13) indicate differences between vegetation types in this respect. Using the soil moisture control section (USDA 1975) as the most reliable indicator of soil water, the highest available water capacity is in chained pinyon-juniper rangeland sites at 0.22 cm H_20/cm soil, followed in decreasing order by bottomland sagebrush (0.19 cm H_20/cm soil), upland sagebrush sites (0.17 cm H_20/cm soil), and pinyon-juniper woodlands (0.17 cm H_20/cm soil) (Table 3-1-6).

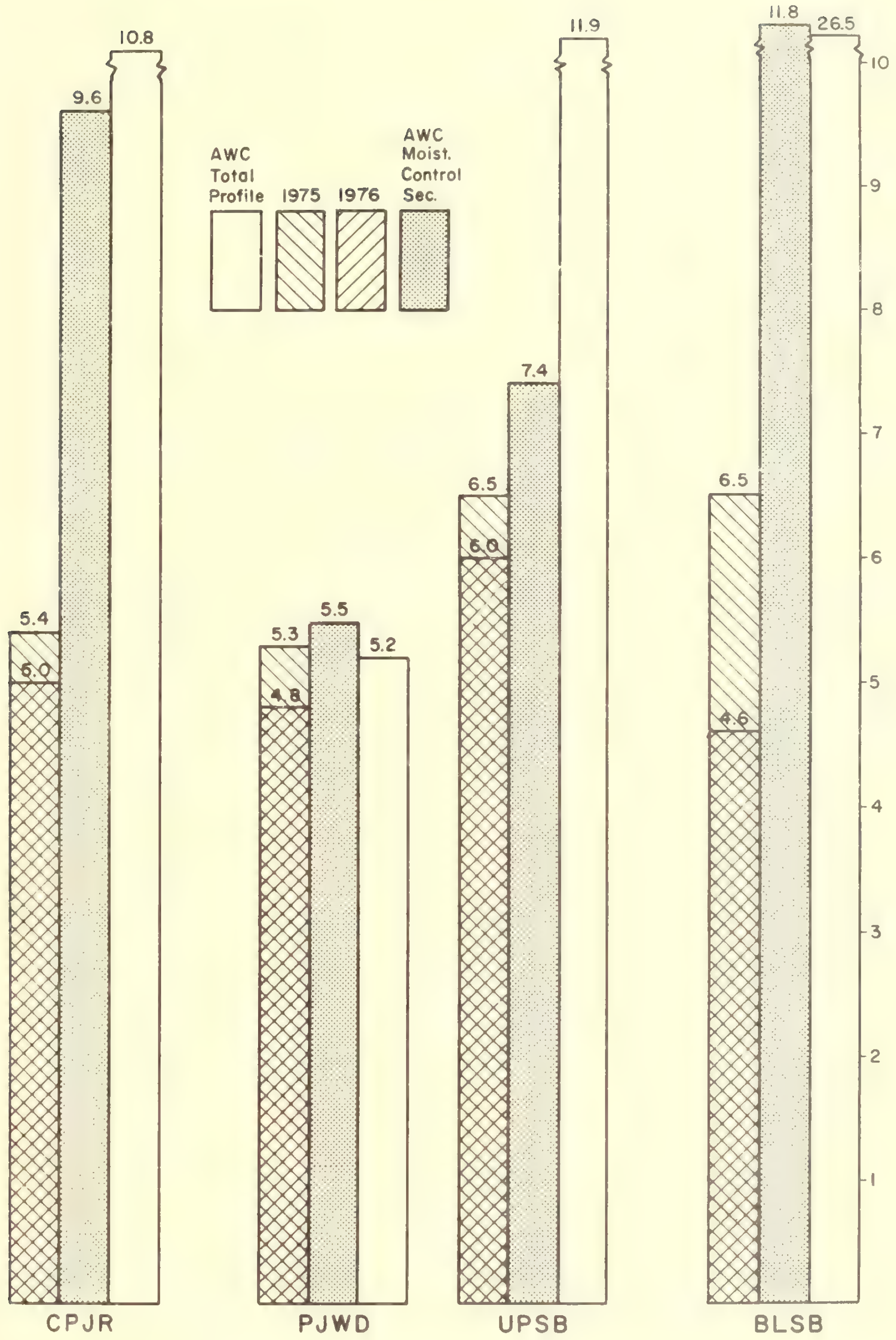
The soil moisture control section for a given soil is roughly defined by the texture of the soil. In loamy, silty, and clayey soils (i.e., soils with fine texture) the section lies between 10 and 30 cm. In coarse loamy soils the soil moisture control section extends from 20 to 60 cm, whereas in sandy soils this section is from 30 to 90 cm (USDA 1975). The soil moisture control section is used as a reference to soil porosity as well as to the soil's ability to develop high internal suctions, and therefore retain water that is unavailable to plants. In this way soil type is an important consideration in discussing available water. Available water tends to increase as the soil texture becomes finer. Sandy soils are generally lowest in available moisture, followed in increasing order by loams, silty soils, and clays (Brady 1974). The flow of water through soils (both saturated and unsaturated) is also influenced by texture. More unsaturated flow occurs in fine textured soils, while more saturated flow occurs in sandy soils. This factor relates

Table 3-1-5

SOIL MOISTURE AND SOIL WATER TENSION FOR MAJOR VEGETATION TYPES, 1975-76
TRACT C-b

	PINYON-JUNIPER WOODLAND						CHAINED PINYON-JUNIPER RANGELAND					
	1975			1976			1975			1976		
	Month	% Soil Moisture	Bars Tension	Month	% Soil Moisture	Bars Tension	Month	% Soil Moisture	Bars Tension	Month	% Soil Moisture	Bars Tension
Annual Maximum	Apr	31	1.5	May	23	10.0	Apr	28	2.0	May	26	3.5
Growing Season Maximum	June	26	6.0	Mar	27	5.0	June	27	2.5	Mar	28	2.0
Annual Minimum	May	14	40.0	July	17	25.0	July	16	25.0	Aug	17	20.0
Growing Season Minimum	May	14	40.0	July	17	25.0	July	16	25.0	Aug	17	20.0

	BOTTOMLAND SAGEBRUSH						UPLAND SAGEBRUSH					
	1975			1976			1975			1976		
	Month	% Soil Moisture	Bars Tension	Month	% Soil Moisture	Bars Tension	Month	% Soil Moisture	Bars Tension	Month	% Soil Moisture	Bars Tension
Annual Maximum	Apr	26	0.2	May	23	0.6	Apr	32	0.04	May	31	0.07
Growing Season Maximum	June	24	0.4	May	23	0.6	June	30	0.1	May	31	0.07
Annual Minimum	Sept	10	20.0	Aug	12	12.0	Sept	15	16.0	July	17	8.0
Growing Season Minimum	Aug	12	12.0	July	13	10.0	May	16	13.0	July	17	8.0



POTENTIAL EVAPORATION AVERAGES OF VEGETATION TYPES IN COMPARISON OF TWO SEASONS

FIGURE 3-1-13

Table 3-1-6 AVAILABLE WATER CAPACITY IN THE FOUR MAJOR VEGETATION TYPES TRACT C-b

Vegetation Type	(1) Surface Thickness (cm)	(2) Horizons A.W.C.*	(3) Soil Moisture Control Section Thickness (cm)	(4) Soil Moisture Control Section A.W.C.	(5) $\frac{\text{cm } H_2O}{\text{cm Soil}}$ (4÷3)	(6) Total Profile Thickness (cm)	(7) Total Profile A.W.C.*
Pinyon-Juniper Woodland	15	4.0	33	5.5	0.17	46	8.3
Chained Pinyon-Juniper Rangeland	15	1.6	43	9.6	0.22	48	10.8
Bottomland Sagebrush	15	3.2	63	11.9	0.19	152	26.5
Upland Sagebrush	15	1.5	46	7.8	0.17	158	23.5

*(A.W.C.) Available Water Capacity = $\dfrac{\text{Bulk Density}\left[\%\text{ Field Capacity} - \%\text{ Permanent Wilting Coefficient}\right]\text{Thickness of sample (cm)}}{100}$

not only to availability of moisture to plants but also to evaporative losses. Sandy or coarse textured soils tend to have higher conductivities and, therefore, supply more moisture to plants and to evaporation. Evaporative effects can extend to a soil depth up to 60 cm through the effects of soil water capillary rise (i.e., conductivity, Brady 1974). This soil water loss is generally equal to approximately 75 percent of the annual rainfall of semi-arid regions.

Temperature and wind also influence evaporation loss. High surface temperatures increase the atmospheric vapor gradient above the soil surface. This effect can be increased by the presence of high winds, such as those occurring at upland sagebrush sites (Figure 3-1-14).

Since the available water capacity of a soil is an indication of the amount of water available for both uptake by plants and evaporation from soil, the AWC value must be adjusted for soil evaporation losses to be a good indicator of soil moisture conditions. Adjusting these values by using a ratio of evaporation to AWC, multiplied by 100, gives an indication of true water status in the soil (Figure 3-1-13). For bottomland sagebrush this ratio is 5.7 ml potential evaporation per day, divided by an AWC of 11.9 cm H_2O, times 100, or 48 percent (Table 3-1-7). In other words, 48 percent of the available water capacity in the soil (in this case figured to a depth of approximately 63 cm) is potentially evaporated in the bottomland sagebrush sites. The ratios of potential evaporation to AWC in the other three types are: pinyon-juniper woodlands

$\frac{5.1 \text{ ml PE/day}}{5.5 \text{ cm } H_2O} \times 100 = 93$ percent; upland sagebrush, $\frac{6.3 \text{ ml PE/day}}{7.8 \text{ cm } H_2O}$ $\times 100 = 81$ percent; and chained rangelands, $\frac{5.2 \text{ ml PE/day}}{9.6 \text{ cm } H_2O} \times 100 = 54$ percent of the AWC potentially evaporated from a depth of approximately 30-45 cm (Tables 3-1-6 and 3-1-7). On this adjusted basis it is apparent that bottomlands have the greatest amount of available moisture, followed in decreasing order by chained rangelands, upland sagebrush, and pinyon-juniper woodlands.

3.1.5.2 Statistical Comparisons Between the Four Microenvironmental Stations

The null hypotheses 1 (no difference between stations) and 2 (no difference between 1975 and 1976) for the four-factor analysis of variance were rejected ($0.0005 < p < 0.001$ and $p < 0.005$ respectively) and the null hypotheses 3 (difference between stations independent of year differences) and 4 (no interaction between parameters, years, and vegetation) were accepted ($p > 0.25$). The null hypotheses 1 and 2 for the three-factor analysis of variance were also rejected

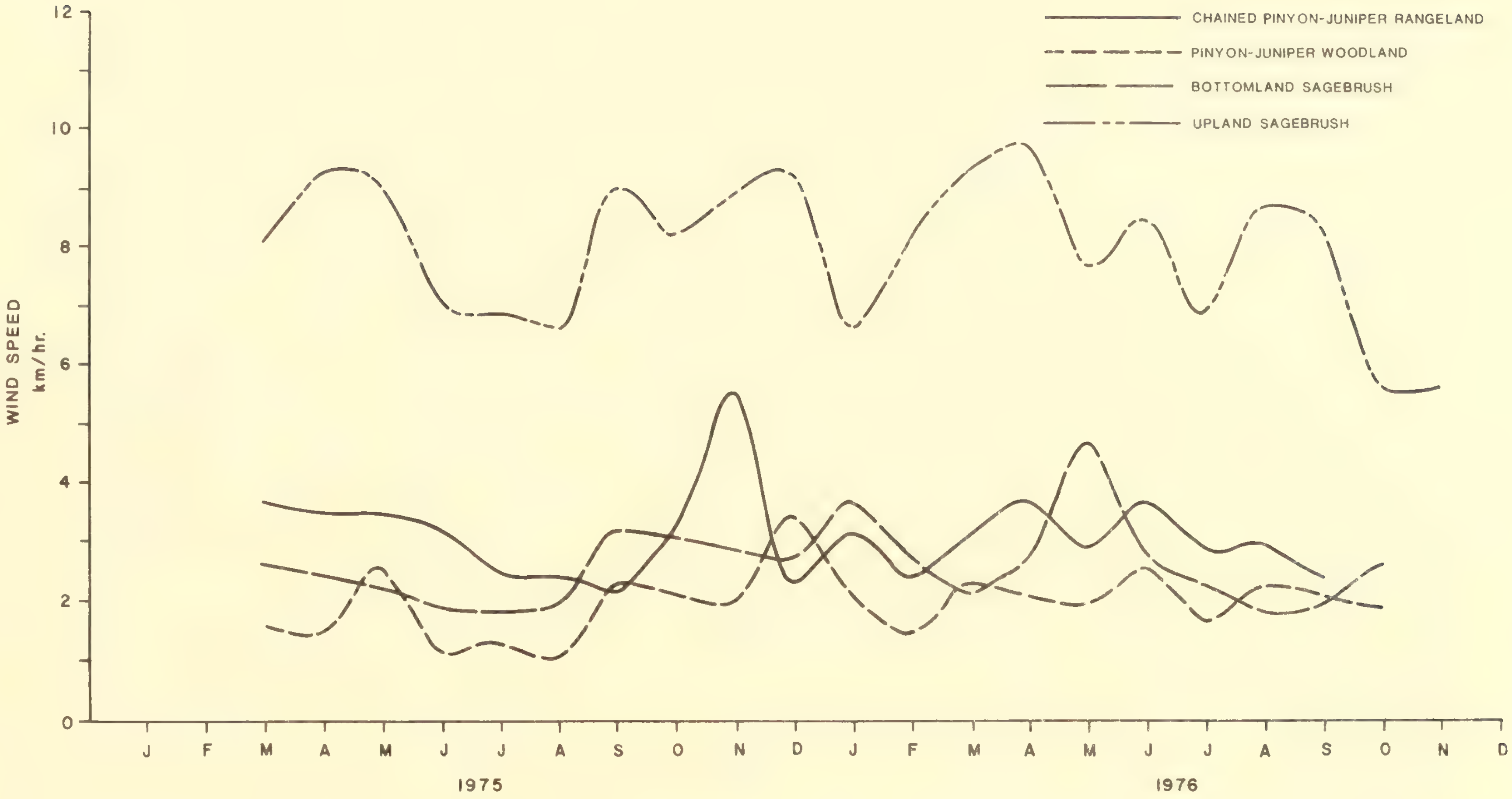


FIGURE 3-1-14 MEAN WIND SPEED FOR THE FOUR MAJOR VEGETATION TYPES, 1975-1976, TRACT C-b

Table 3-1-7 POTENTIAL EVAPORATION* IN THE FOUR MAJOR VEGETATION TYPES TRACT C-b

Vegetation Type	*P.E. 1975	P.E. 1976	Mean P.E. 1975-1976	$\frac{\text{P.E.}}{\text{A.W.C.}}$ Soil Moisture Control Section	% Water Evaporated From Soil Moisture Control Section
Pinyon-Juniper Woodland	5.3	4.8	5.1	$\frac{5.1}{5.5}$	92.7
Chained Pinyon-Juniper Rangeland	5.4	5.0	5.2	$\frac{5.2}{9.6}$	54.2
Bottomland Sagebrush	4.5	4.6	5.7	$\frac{5.7}{11.9}$	47.9
Upland Sagebrush	6.0	6.5	6.3	$\frac{6.3}{7.8}$	80.8

($0.01 < p < 0.025$ and $p < 0.0005$ respectively) and the null hypotheses 3 and 4 were accepted ($p > 0.25$).

Therefore, we conclude that there are differences between the microenvironments of the stations and the years 1975 and 1976, but these differences are independent of each other. It is also concluded that there is no significant interaction between the effects of the parameters, years (1975-1976), and the vegetation types on the microenvironments.

The null hypothesis for the two single factor analyses of variance was accepted ($p > 0.25$). Therefore, we conclude that the differences between the four vegetation types are not due to total precipitation or mean soil moisture.

The series of hypotheses tested by the Newman-Keuls test show that when the microenvironment is measured in terms of ambient, surface, and -20 cm soil temperatures, there exist two groups with similarities. Two of the vegetation types, chained pinyon-juniper rangeland and bottomland sagebrush, belong to both groups. These results are ambiguous, the test was unable to determine accurately in which group to place chained pinyon-juniper rangeland and bottomland sagebrush. However, it does indicate that the microenvironment, in terms of temperature, is different when comparisons are made between pinyon-juniper woodland and upland sagebrush. This difference is to be expected due to the extreme differences in canopy between the two vegetation types. As previously mentioned the canopy regulates the amount of solar insolation reaching the surface and reradiating from the surface.

It can be concluded from the series of hypotheses tested that the differences in the microenvironments among the four major vegetation types are most likely due to the unique make-up of each vegetation type (i.e., vegetation and soils). The outside influences tested, such as precipitation and yearly fluctuations in temperature and precipitation did not significantly influence the microenvironments of the four vegetation types. However, constituents of the vegetation types, in the Newman-Keuls test did influence differences in the microenvironment of the PJWD and BLSB vegetation types.

These conclusions point to an interaction between vegetation and soils modifying their respected microenvironments.

3.2 Soils

Soil studies on Tract C-b have five components: 1) the identification and mapping of soil units (series); 2) soil sampling and chemical/physical analysis; 3) greenhouse soil productivity studies; 4) soil-plant interrelationships studies; and 5) soil biotic studies.

The U. S. Soil Conservation Service (SCS) identified and mapped the seven major soil units within the Tract C-b study area in 1975. Soil and vegetation data collected during the Tract C-b studies were analyzed statistically to determine correlations between soil constituents and vegetation.

3.2.1 Rationale

Soils are an integral part of the structural and functional dynamics of the biological system. Together with vegetation--acting through the influence of climatic conditions--they form the basis of important geochemical cycles which effect other biota, particularly major herbivores. The combined effects of soils, vegetation, and climate are the production of habitat.

Soil microorganisms, specifically plant forms such as bacteria, actinomycetes and fungi, are important contributors in the final stages of organic matter decomposition, the synthesis of humus, and the production of compounds simple enough for the direct nutrition of higher plants. Because these microorganisms are critical components in the biochemical transformation of organic material for use by higher plants, perturbations which affect their abundance or functioning will ultimately affect the entire food chain.

3.2.2 Objectives

Soil studies were undertaken in order to accomplish two primary ends: 1) to document baseline conditions of soil distributions, soil physical and chemical characteristics, and productivity; and 2) to elucidate the relationships between soils and vegetation.

In order to detect changes which may occur in the abundance or distribution of soil microorganisms, the abundance of several important groups were selected for measurement of baseline conditions. The groups included: total bacteria, total bacteria showing denitrification, nitrifying bacteria, actinomycetes, and fungi.

3.2.3 Experimental Design

3.2.3.1 Soil Survey/Mapping

Soil mapping units were identified using aerial photography in combination with ground-checking. Control pits were excavated in each of the major units to facilitate the physical description of each soil and to facilitate the sampling of soil horizons for physical and chemical analysis.

3.2.3.2 Soil Nutrients

Sampling of soils for physical and chemical analysis was carried out in two related efforts: 1) initial sampling of control pits used for describing soils and 2) additional sampling of soils located in vegetation sampling stands.

3.2.3.3 Soil Productivity

Soil samples for greenhouse studies were obtained at seven sites. The sampling sites correspond to the six permanent vegetation sampling sites and to the one small mammal trapping site. A general analysis was made prior to sampling to determine if soils of the sampling locations had some differing characteristics. Soil samples from each site were transported to greenhouse facilities and divided in flats.

3.2.3.4 Soil-Plant Interrelationship Studies

In the 1st Annual Summary and Trends Report for Tract C-b (Olgeirson and Odening 1976) gradient analyses were reported for selected soil parameters with corresponding shrub importance values and herbaceous species frequencies. These gradient analyses did not reveal the evidence of strong trends between soil constituents and vegetation. The analyses did strongly imply certain relationships between soils and vegetation that are limiting to the growth of species and that act as controls on species distributions. The analysis also showed preliminary evidence for interspecific competition. These results suggested additional, more sophisticated, analyses were needed to examine the relationship between soil and vegetation and the relationships between plant species in greater depth.

Soil physical and chemical analyses obtained from the surface horizon (15-25 cm, approximate depth) of 25 soil samples were entered into a computer data base along with site specific data for the herbaceous frequency of eight species and shrub importance values for seven species. Analysis was conducted to clarify any demonstrable interrelationships. Vegetation data were obtained from identical sites as the soil samples.

Soil and vegetation data were subjected to analysis of variance techniques. The analysis of variance used five distinct treatments for comparisons of soil and vegetation parameters: 1) soil constituents were compared with soil constituents; 2) herbs were compared to herbs; 3) shrubs were compared with shrubs; 4) herbs were compared with soils; and 5) shrubs were compared with soils. All treatments were carried out using data from the 25 sampling locations.

Regression equations were also computer-generated for herb frequency values and soils; and for shrub importance values and soil parameters. Both first and second degree regression equations were developed, along with a coefficient of determination for each equation for each soil and vegetation parameter. Regression lines were plotted for each plant-soil regression analysis performed for both the first and second degree regression equation. Results were interpreted at the 90 percent and 95 percent levels of statistical confidence and were also analyzed at the 75 percent level as the lowest level of biologically important reference.

3.2.3.5 Soil Biotic Studies

Soil samples were obtained on Grids 1 and 2 in areas not disturbed by activities related to other studies such as small mammal trapping or arthropod collections. Sampling was conducted during August 1975 and July 1976.

3.2.4 Methods

3.2.4.1 Soil Survey/Mapping

Soils were mapped and described on the SCS using USDA standard techniques and terminology (USDA 1960). Detailed descriptions of each soil type are in Appendix IV-B, Section 2.

3.2.4.2 Soil Nutrients

Soil samples were analyzed by Agricultural Consultants Laboratory. The laboratory methods used are outlined below in brief. Specific methodologies are referenced for more specific data.

Each representative soil series was sampled by horizon throughout the profile. Additional samples were taken from eighteen vegetation sampling locations. Additional sampling was done in the top 15 to 25 cm of soil and was conducted throughout each of the stand locations chosen. Complete results of sort analyses are in Appendix IV-B, Section 2.

3.2.4.3 Soil Productivity

Twenty-one experimental flats were established, including controls. Each flat was subdivided into two parts. The seeds from two selected bioassay species were planted in each half of each flat. The species selected for bioassay were oats (Avena sativa var. victory) and barley (Hordeum vulgare var. Briggs). Control flats were established using vermiculite treated with Hoaglund's solution as a nutrient source. Each flat was planted with a total of 50 seeds of each species for a total of 150 seeds of each species per soil type.

Germination rates of the two species were measured in each soil type and in the control substrate. Growth parameters were measured on 15 plants of each species in all flats for four weeks following germination. The plants were selected for measurement utilizing a random numbers table. Measurements were made of total stem length, number of nodes, internodal length, and leaf length. Growth rate analysis was ultimately conducted on the total plant height only.

At the end of the four week growth period, the plants were harvested. All plants were removed from the soil, and the shoot lengths were measured, dried and weighed to get an oven-dry weight of biomass accumulated over a four-week period. Subsamples of each soil sample were analyzed. The shoot length and biomass data were treated to graphical and statistical analysis to substantiate the significance of the differences in the observed productivity of the various soils.

3.2.4.4 Soil-Plant Interrelationships

3.2.4.4.1 Vegetation

Shrub and herb species were sampled in 29 stands representing each of the following vegetation types: 1) pinyon-juniper woodland, 2) chained pinyon-juniper rangelands, 3) upland sagebrush, 4) bottomland sagebrush, 5) bunchgrass, 6) rabbitbrush, 7) greasewood, 8) Douglas-fir forest, and 9) annual weed communities.

Shrub parameters collected include density, cover, and frequency of species. Herb parameters include frequency by species and cover. Shrubs were sampled using a modified belt transect method (Lindsey 1955). Five, 50-meter transects were located in each sampling site; 20, one-square meter herb quadrats were located along each belt transect. Shrub importance values were generated from relative values of density, cover, and frequency in each stand using the formula: Importance Value = Relative Frequency + Relative Density + Relative Cover. Relative values are obtained by dividing the actual species value for frequency, density, or cover by the appropriate total stand value. Herb frequencies were developed directly from frequency notations obtained in field sampling.

3.2.4.4.2 Soils

Soils were sampled in each of the vegetation sampling stands. Soils were collected by a cumulative sampling method, so that each sample represents a number of smaller samples taken throughout a given sampling location. Soils were analyzed by standard laboratory methods for the following parameters: nitrate-nitrogen, nitrate-ammonia, phosphate, potassium, calcium, magnesium, sulfate-sulfur, iron, manganese, zinc, copper, boron, cation-exchange-capacity, pH, percent lime, salts-electrical conductivity, percent permanent wilting coefficient, percent field capacity, percent available water, percent organic matter, and organic matter nitrogen available in one year from decomposition of organic material.

3.2.4.4.3 Statistical Analysis

Two standard statistical analysis methods were applied to the soil and vegetation data collected: 1) analysis of variance, and 2) regression and correlation analysis.

The statistical methods were applied to the data in order to assess the significance of interactions between soil and vegetation parameters and between herb species, shrub species, and soil parameters.

Specifics of these methods are in Appendix IV-A, Section 2. Statistical analysis data are in Appendix IV-B, Section 2.

3.2.4.5 Soil Biotic Studies

Replicate soil samples were collected beneath mountain mahogany, selected as a representative shrub species, and from open ground with no shrub overstory. Soil samples were taken to a depth of 20 cm to include soil horizons which generally include the majority of soil microbes. Samples were analyzed for the abundance of total bacteria colonies, actinomycetes, fungi, percent of total bacterial showing denitrification, and the presence of nitrifiers (Appendix IV-A, Section 2).

3.2.5 Results and Discussion

3.2.5.1 Soil Survey

The soil classification for soils identified on the Tract is presented in Table 3-2-1. The soil series units are mapped on Pocket Figure 3-2-1 (refer to pocket, inside back cover).

Table 5-2-1 SOILS OF TRACT STUDY AREA

(USDA Soil Classification System, 1960)

ORDER	SUBORDER	GREAT GROUP	SUBGROUP	FAMILY	SERIES
ARIDISOLS	Argid	Haplargids	Borallic	Fine Loamy Mixed	Forelle Loam
	Orthids	Camborthids	Borallic	Fine Loamy Mixed	Piceance Fine Sandy Loam
ENTISOLS	Fluvents	Torrifluvents	Ustic	Coarse Loamy Mixed (Cal.) Frigid	Glendive Fine Sandy Loam
			Ustic	Sandy Mixed Frigid	Rivra Loam
			Typic	Fine Loamy Mixed (Cal.) Frigid	Hagga Loam
	Orthents	Torriorthents	Lithic-Ustic	Loamy Mixed (Cal.) Frigid	Redcreek-Rentsac Complex
			Lithic-Ustic	Loamy Skeletal (Cal.) Frigid	Rentsac Channery

Key to Suffixes and Prefixes: Arid = dry; Arg = Clayey; Hapl = minimum horizon; Bor = cool, high organic; Orth = typical; Camb = altered; Ent = recent; Fluv = deposited by water; Torri = dry, low organic; Ust = dry, summer rains; Typ = typical; Lith = rocky

Other Terminology: Cal. = calcareous; Skeletal = interspersed with rock; Channery = containing fine pieces of sandstone or shale

3.2.5.1.1 Classification of Soils

3.2.5.1.1.1 Identification of Soil Taxonomic Units

The soils are classified using the U. S. Department of Agriculture's Soil Classification System (USDA 1975) adopted for use by the National Cooperative Soil Survey. This is a hierarchial system consisting of six major categories. Each category defines soils at a particular level of abstraction. The highest and broadest category (Soil Order) is useful for studying or comparing soils of very large areas such as countries and continents. The lowest category (Soil Series) defines soils very specifically and is used in detailed surveys.

3.2.5.1.1.2 Interpretations of Soil Taxonomic Units with Respect to Soil Moisture

Names of soils at Order, Suborder, and Great Group category levels include an identification of the soil moisture regime which refers to the presence of ground water or of water held in the soil at a tension of 15 bars during various periods of the year in the "soil moisture control section." The soil moisture control section is roughly defined by depth and particle size, e.g., a depth of 10 cm to 31 cm, if the particle-size class is fine-loamy, coarse-silty, fine-silty, or clayey; it is defined by a depth of 20 to 61 cm if the particle-size class is coarse-loamy, and the 30 to 89 cm if the particle-size class is sandy (USDA 1975).

The moisture regime helps in understanding the amount of soil development, the nature and distribution of organic matter, base status, and the amount of leaching. The greatest significance, however, is related to the potential for growing different plants.

The soil moisture regimes pertinent to the Tract are torric and ustic (USDA 1975). Torric soils are dry for the greater part of the growing season, are never totally wet and thus, are deficient in moisture for plant growth. Little or no leaching occurs in this moisture regime and soluble salts will accumulate if there is a source for them. Many of the soils in this moisture regime either have physical properties that keep them dry, such as a crusty surface which retards infiltration, or they are shallow over bedrock. In the study area this soil moisture regime includes the Torrifluvents and Torriorthuents (Table 3-2-1). Weathering of geologic materials exposed in this environment is extremely slow.

In ustic soils overall moisture is limited but there is a surplus of moisture (where precipitation exceeds evapotranspiration) in fall and early winter. Leaching can occur during this period. During the spring and early summer, even though evapotranspiration exceeds precipitation, sufficient moisture is available for plant growth but very little leaching occurs. Summer is a period of moisture deficiency, limiting growth and the establishment of plants. Soils in the study area having this soil moisture regime are the Haploborolls, Haplargids, Camborthids, and Fluvaquents (Table 3-2-1).

3.2.5.1.1.3 Interpretation of Soil Taxonomic Units with Respect to Soil Temperature

The temperature of a soil is one of its most important properties. Within limits it controls the possibilities for plant growth and soil formation or development by controlling biotic activity and rates of other soil-forming processes.

The soils of the Tract are included in the frigid and soil temperature regimes. A frigid soil has a mean annual temperature lower than 8°C (47°F). Frigid soils of the study area include Torrifluvents, Torriorthents, Haplargids, Fluvaquents, Haploborolls, and the Camborthids (USDA 1975).

3.2.5.1.1.4 General Description of Soil Taxonomic Units

The following is a general description for soils at the Suborder level found on the Tract.

3.2.5.1.1.4.1 Argids

The argid soils are characterized as having thin, light-colored surface horizons low in organic matter but high in base status. These soils are dry for long periods of time. Because of the low organic matter and generally fine texture (high clay content), some soils in this group take up water slowly and most rainfall runs off. Clays may offer high shrink-swell potential, and water and wind erosion are additional potential hazards. Except for a low nitrogen supplying ability, these soils generally have a moderate-to-high fertility status. One argid soil occurs in the study area - a Forelle fine sandy loam (map unit 71C-Pocket Figure 3-2-1, Table 3-2-1).

3.2.5.1.1.4.2 Fluvents

Fluvents are subject to flooding but are not perpetually wet. The parent materials are alluvial sediments and may contain appreciable amounts of organic matter. These soils are highly stratified and their chemical and physical properties vary with depth. Soils in this category could be a valuable source of plant growth medium for covering processed oil shale or coarse geologic materials. Fluvents are an important soil suborder in the Tract study area and include Glendive Loam (41), Rivra Loam (75), and Hagga Loam (9).

3.2.5.1.1.4.3 Orthents

Orthents are the most common soils on the Tract. Orthent soils are found in areas where little or no soil development is present, e.g., uplands and on erosional surfaces. They have a low organic content and low fertility. Landscapes on which these soils occur are subject to water erosion.

The two series identified as orthents are the Redcreek-Rentsac Complex and Rentsac Loam. These soils underlie pinyon pine-juniper woodlands and chained areas.

3.2.5.1.1.4.4 Orthids

The orthids are similar to the argids but without strongly developed subsoil. They are either chronologically younger than the argids, or because of slope, parent material, or climatic conditions, or a combination of these soil development has been retarded. If the latter is the case, this suggests that the soils occur on active erosional surface and that the degree of severity of droughtiness as well as erosional hazard may be great. These soils have thin, light-colored surface horizons low in organic matter and may have a horizon of salt accumulation. The Piceance (70) series is an orthid occurring in the study area.

3.2.5.1.1.5 Classification of Soils on the Tract

Classification of the soils on the Tract is outlined in Table 3-2-1. All of the soils exhibit some common characteristics. They are in areas that have an average annual precipitation of 380 mm; the average annual air temperature ranges from 42-45°F. The frost-free period varies from 80 to 105 days, which means the growing season is short. Most of the soils on Tract C-b are best suited for livestock grazing and wildlife habitat. Table 3-2-2 and Pocket Figure 3-3-2 (Vegetation Section, 3.3) show the vegetation associations of the soils found on the Tract. Classification of Tract soils and their descriptions follow (USDA 1975).

3.2.5.1.1.5.1 Aridisols - Argids - Haplargids #71C Forelle Loam, 3 Percent to 8 Percent Slopes

A deep, well-drained soil on uplands and terrace slopes at elevations of 1828 to 2200 meters, the Forelle formed in fine-textured aeolian deposits. Typically, the surface layer is a brown loam about four inches thick with a brown, light clay-loam subsoil, 31 cm thick. The substratum is a very pale brown loam extending to more than 152 cm. Lime accumulates in strong lenses in the lower

Table 3-2-2 SOILS AND VEGETATION ASSOCIATIONS OF THE TRACT C-b STUDY AREA

Vegetation Type	Soils						
	HAGGA LOAM	GLENDIVE LOAM	RIVRA LOAM	PICEANCE LOAM	FORELLE LOAM	RENTSAC CHANNERY	REDCREEK RENTSAC-COMPLEX
PINYON-JUNIPER WOODLAND				X	X	X	X
CHAINED PINYON-JUNIPER RANGELAND				X	X	X	X
BOTTOMLAND SAGEBRUSH		X	X				
UPLAND SAGEBRUSH				X	X	X	X
MIXED MOUNTAIN SHRUBLAND						X	X
DOUGLAS-FIR FOREST						X	
BUNCHGRASS COMMUNITY					X	X	X
GREASEWOOD COMMUNITY			X				
RABBITBRUSH COMMUNITY		X					
GREAT BASIN WILDRYE COMMUNITY		X					
AGRICULTURAL MEADOWS	X	X	X				
RIPARIAN COMMUNITY	X	X					

subsoil and substratum; permeability is moderate; effective rooting depth is 152 cm or more; available water capacity is medium; and surface runoff is slow and erosion hazard slight. The soil is used for dryland farming, livestock grazing, and wildlife habitat. It is a good source for fine soil material.

Forelle loam is strongly associated with upland sagebrush communities and may offer a partial explanation for the occurrence of this vegetation type within some pinyon-juniper woodlands and chained rangelands. This soil differs from the Redcreek and Rentsac series commonly underlying the pinyon-juniper vegetation type in being composed of fine, wind-deposited materials, in having a generally higher nutrient status, and in maintaining higher field-capacity levels. This soil is somewhat deficient in potassium and phosphorus (probably as a result of a high pH of 8.4) but is high in available nitrogen. All soils in the study area are deficient in zinc.

Forelle loam is also found locally underlying pinyon-juniper woodland and chained rangeland and underlying bunchgrass communities on west-facing slopes.

3.2.5.1.1.5.2 Aridisols - Orthids - Camborthids
#70 Piceance Fine Sandy Loam,
5 Percent to 15 Percent Slopes

This is a moderately deep, well-drained soil on upland slopes and ridges at elevations of 2000 to 2300 meters. Formed in residuum from sandstone and modified with aeolian material, the surface layer develops to a brown, fine-sandy loam about 25 cm thick with a moderate amount of organic material. The subsoil is composed of 51 cm of light yellowish-brown loam over a substratum of very pale brown, very channery sandy loam about 15 inches thick. Lime accumulates in the lower subsoil and substratum and permeability is moderate. Effective rooting depth is 51 to 102 cm, and available water capacity is moderate in this soil type. Surface runoff is slow to medium and erosion hazard slight to moderate. It is a fair to poor source for topsoil because of the depth to rock.

Although it has minimal correspondence with the occurrence of pinyon-juniper woodlands and chained rangelands, the vegetative association of the Piceance Loam is similar to that of the Forelle loam, e.g., upland sagebrush. Vegetation associated with this soil is used for livestock grazing and wildlife habitat. This soil is high in nitrates and low in potassium and phosphorus (pH 8.3).

3.2.5.1.1.5.3 Entisol - Fluvents - Torrifluvents #41 Glendive Fine Sandy Loam, 2 Percent to 15 Percent Slopes

This is a deep, well-drained soil found on valley bottoms over a wide range of elevations (1800 to 2300 meters). Formed in mixed alluvial materials, the surface layer is a pale brown, fine-sandy, loam about 31 cm thick containing some organic material. The substratum consists of stratified loams, sandy loams, and loamy sands to a depth of more than 152 cm with a similar effective rooting depth. Available water capacity is moderate. With a moderate permeability, surface runoff is slow and erosion hazard slight.

Glendive fine sandy loam predominately underlies bottomland sagebrush communities and agricultural meadowlands. Table 3-2-2 indicates other, minimal associations of this soil series. This soil is used for irrigated pasture, livestock grazing, and wildlife habitat.

The chemistry is complex and the nutrient level high. The deleterious nature of the sodium sulfate and the total salt concentrations may be counteracted by substantially high nitrate levels. This soil is high in potassium and phosphorus; the effects of high pH (8.7) are apparently counteracted by high sulfate levels.

3.2.5.1.1.5.4 #75 Rivra Channery Loamy Fine Sand, 2 Percent to 9 Percent Slopes

This is a very deep, somewhat exclusively-drained soil on alluvial fans and cones and on narrow stream bottoms at elevations between 1800 and 1980 meters. Parent material is sandstone or mixed sandstone and shale. Typically the surface layer is pale brown, channery, loamy, fine sand about 15 cm thick with a low organic content. The next layers consist of 94 cm of light, yellowish-brown, channery sand overlying 94 and 152 cm of pale brown and light, yellowish-brown, channery sand, very channery sand, and channery, loamy, fine sand. This soil is highly calcareous. Effective rooting depth is 152 cm or more; available water holding capacity is low; permeability is high; surface runoff is slow; and erosion hazard is medium.

Vegetation associated with the Rivra soil includes bottomland sagebrush, greasewood stands, and agricultural meadows which have fair potential for supporting cottontail and deer. These mammals use the grasses, forbs, and brush on these soils and obtain their shelter primarily from the brush. This soil is dry and shows high values for nitrogen, potassium, and phosphorus, but has excessive concentrations of both sodium and sulfate.

3.2.5.1.1.5.5 #9 Hagga Loam, 0 Percent to 5 Percent Slopes

This is a very deep, poorly-drained soil on floodplains at elevations of 1800 to 2050 meters. It is formed in calcareous alluvium from mixed sandstone and shale sources. The surface layer is loam, about 64 cm thick and, except for dark lenses, is light gray. The surface layer is underlain by light gray clay-loam. Rust-colored iron mottles are common throughout the soil. Permeability of the Hagga loam is moderate to low; effective rooting depth is 152 cm or more; available water holding capacity is high; organic matter content in the surface layer is medium; surface runoff is very slow with some ponding; and erosion hazard is slight.

This soil is used for native and seeded grass hay, with limited acreage seeded to small grain for hay. Yields of the more desirable grasses and small grains are medium. In the fall, migratory ducks utilize the grasses on Hagga soils finding most of the seeds in poorly drained areas too wet to mow for hay. In evenings deer concentrate on Hagga soil for the water associated with it.

This soil, as with most of those on or near the Tract, has a high pH value which results in low available phosphorus; nitrate levels are also high.

3.2.5.1.1.5.6 Entisols - Orthents - Torriorthents #66 Redcreek-Rentsac Complex, 50 Percent to 30 Percent Slopes

These moderate-to-steep sloping soils are formed in residuum on foothill slopes and ridges at elevations of 1800 to 2300 meters. The Redcreek soil makes up about 60 percent of the mapping unit #66 and the Rentsac soil makes up about 30 percent. The Redcreek soil is a shallow, well-drained soil formed in residuum from massive, rapidly weathering sandstone. Typically, the surface layer is a pale brown, sandy loam about 31 cm thick and rests on massive sandstone; permeability is moderate to high; the effective rooting depth is 25 to 51 cm; the available water capacity is low; and surface runoff is slow and erosion hazard is slight. The Rentsac soil is a shallow, well-drained soil that formed in residuum from highly fractured, hard sandstone. Typically, the surface layer is a pale brown, very channery, sandy loam about seven inches thick and rests on hard fractured sandstone. Permeability is high; effective rooting depth is 25 to 51 cm and available water capacity is low; surface runoff is slow and erosion hazards slight. The thin soil layers make these soils unsuited for use as topsoil.

The Redcreek series is a dry, shallow soil low in fertility. Potassium and phosphorus are low but nitrates are adequate. This soil is commonly associated with pinyon-juniper woodland and chained rangeland and also underlies bunchgrass communities, mixed mountain brush communities and upland sagebrush. Bunchgrass and upland sagebrush communities associated with this and the following #63 Rentsac series are frequently on burned sites. These soils are used for limited livestock grazing and for wildlife habitat.

3.2.5.1.1.5.7 #63 Rentsac Very Channery, Fine Sandy Loam, 5 Percent to 50 Percent Slopes

This is a shallow, well-drained soil on foothills and ridge tops at elevations of 1800 to 2300 meters. It is formed in residuum on sandstone that is usually horizontally fractured. The Rentsac soil comprises about 70 percent of the map unit #63. The surface layer is a pale brown, very channery, sandy loam about four inches thick. The underlying layer is a pale brown, very channery, sandy loam about seven inches thick. The substratum is a pale brown, very flaggy, sandy loam about seven inches thick and overlies fractured hard sandstone. Permeability is high; effective rooting depth is less than 51 cm. Organic matter content in the surface layer is medium; available water capacity is low; and surface runoff is medium and erosion hazard is slight-to-moderate. As a source material for topsoil, Rentsac is poor because of its thin layering, inclusion of small stones (gravelly nature), and problems of reclamation of the borrow area.

The Rentsac channery supports plant communities similar to the Redcreek series, but with the addition of Douglas-fir, and it is not as strongly associated with upland sagebrush. This soil is used for recreation and livestock grazing. It is shallow and dry and has low fertility.

3.2.5.2 Soil Chemical and Physical Analysis

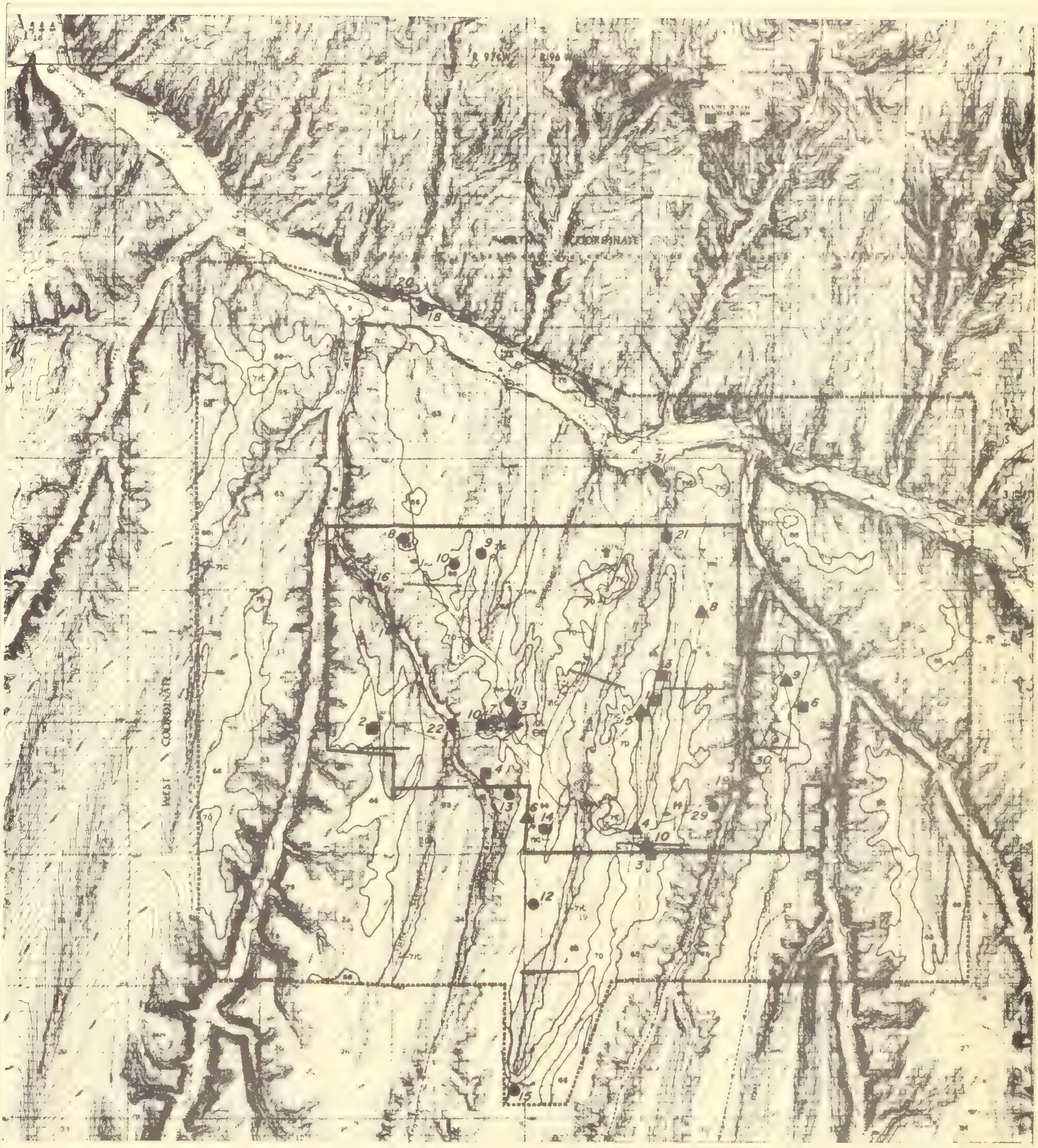
A summary of the chemical and physical characteristics of soils analyzed is shown in Table 3-2-3; sampling locations are shown on Figure 3-2-2. A brief discussion of the significance of these soil characteristics can be found in Appendix IV-B, Section 2.

The texture of the soils on the Tract range from light to medium. The four textural categories include: (1) sandy loam, (2) sandy clay loam, (3) clay, and (4) silty clay loam. Percent Organic Matter is generally moderate (ca 2 percent) but is high in several samples (ca 5 percent). Percent lime in the surface is characteristically high (>5 percent), as is pH (i.e., pH is basic <8). Cation Exchange Capacity is moderate (ca 20 mg equiv/100 gm). Electrical Conductivity of soils is low to average (1.0 MMHOS/cc), except in sagebrush bottomlands and in greasewood stands, both of which have excessively high values (>4.0 MMHOS/cc). Nitrogen estimated to be available from organic matter decomposition in one year's time is generally

Table 3-2-3 SUMMARY OF SOIL PHYSICAL AND CHEMICAL CHARACTERISTICS

SAMPLE NO.	NO_3+ -N	NH_4 -N+	P	K	Ca	Mg	SO4 -S	Fe	Zn	Cu	Mn	B	CEC (1)	pH	% LIME	SALT	ESP (2)	PWC (3)	FC (4)	% AW (5)	OM (6)	TEXTURE	[illegible]	TYPE	SOIL
01	5.	0.3	6.	120.	4900.	200.	17.	5.2	0.5	0.7	1.0	0.5	33.0	8.5	4.6	0.3	1.5	11.0	23.0	12.0	2.8	SNCLLO	112.0	[illegible]	63
02	27.	0.4	26.	130.	2900.	380.	6.	10.0	0.4	0.3	1.9	0.8	22.0	8.2	1.0	0.5	2.3	10.0	22.0	12.0	3.2	SILO	128.0	[illegible]	[illegible]
03	6.	0.2	16.	250.	2600.	550.	37.	7.2	0.5	0.8	3.7	0.8	23.0	7.8	0.3	0.3	2.6	14.0	25.0	11.0	3.6	SICLLO	126.0	UPSB	[illegible]
04	10.	0.2	2.	300.	3400.	230.	10.	2.6	0.2	0.5	0.9	0.9	25.0	8.2	6.0	0.3	2.0	10.0	23.0	13.0	3.2	SILO	128.0	BLSB	[illegible]
05	7.	0.4	7.	130.	4200.	290.	27.	9.7	0.5	0.5	1.4	0.5	30.0	8.4	4.6	0.3	1.7	16.0	28.0	12.0	5.1	[illegible]	[illegible]	[illegible]	[illegible]
06	7.	0.4	24.	220.	2600.	410.	14.	29.0	3.6	1.3	9.6	0.6	21.0	7.2	0.8	0.3	1.9	18.0	33.0	15.0	6.2	SICLLO	217.0	PJWD	[illegible]
07	5.	0.6	8.	140.	5400.	390.	30.	1.6	0.1	0.2	0.9	0.5	37.1	8.3	8.5	0.7	1.2	18.9	25.4	6.5	2.4	SNCLLO	96.0	CPJP	[illegible]
08	10.	1.0	1.	70.	5000.	360.	16.	1.2	0.1	0.3	0.9	0.4	34.4	8.4	8.8	0.7	1.6	23.1	29.6	6.5	2.1	CLLO	84.0	UPSB	[illegible]
09	20.	2.0	18.	130.	4900.	220.	20.	5.3	0.2	0.3	1.7	0.6	32.2	8.1	5.9	1.0	1.6	17.4	23.7	6.3	3.0	SNCLLO	120.0	PJWD	63
10	12.	2.0	11.	130.	5200.	240.	5.	3.0	0.1	0.3	1.5	0.6	34.3	8.2	4.5	0.9	1.4	20.3	26.8	6.5	4.6	SNCLLO	120.0	[illegible]	[illegible]
11	4.	0.5	2.	80.	4700.	740.	25.	2.4	0.3	0.4	1.3	0.5	35.7	8.3	5.9	0.8	1.1	25.4	32.7	7.3	2.3	SICLLO	[illegible]	UPSB	70
12	7.	0.9	6.	93.	4900.	370.	25.	4.4	0.1	0.3	1.3	0.6	33.7	8.2	7.3	0.8	1.2	17.8	24.0	6.2	2.4	SICLLO	96.0	[illegible]	[illegible]
13	7.	0.8	1.	46.	4800.	190.	12.	2.0	0.1	0.2	1.0	0.4	31.5	8.3	9.0	0.7	1.4	17.2	23.1	5.9	2.3	SNCLLO	[illegible]	PJWD	[illegible]
14	7.	1.3	9.	89.	6100.	390.	18.	3.0	0.4	0.3	1.5	0.6	41.1	8.2	7.4	0.8	1.1	19.3	25.6	6.3	3.5	SNCLLO	120.0	[illegible]	[illegible]
15	4.	0.5	2.	95.	4500.	580.	20.	4.5	0.6	0.5	3.0	0.5	33.2	8.1	1.3	0.7	1.1	24.7	31.2	6.5	2.4	CLLO	96.0	UPSB	71C
16	14.	2.0	6.	130.	4600.	240.	40.	4.4	0.4	0.3	2.1	0.7	30.9	8.2	5.8	0.8	1.7	18.4	24.6	6.2	3.7	SNCLLO	120.0	BLSB	[illegible]
18	10.	1.3	4.	360.	3600.	350.	35.	4.8	0.1	0.4	1.5	0.7	27.4	8.6	7.4	1.4	7.9	7.4	9.3	1.9	2.7	SNLO	100.0	[illegible]	[illegible]
19	15.	1.5	2.	230.	3800.	190.	25.	4.1	0.1	0.3	1.7	0.6	25.6	8.2	3.8	1.1	2.2	11.1	17.3	6.2	2.0	SNLO	90.0	BLSB	[illegible]
20	9.	0.7	2.	100.	3100.	180.	25.	3.2	0.1	0.3	1.4	0.6	21.4	8.5	5.1	1.1	4.7	8.6	10.4	1.8	1.4	SILO	63.0	[illegible]	63
21	5.	1.1	14.	70.	5600.	280.	30.	7.0	0.1	0.3	2.5	0.6	37.2	8.1	7.6	0.9	1.9	14.7	20.3	5.6	4.3	SNLO	120.0	[illegible]	[illegible]
22	7.	0.7	1.	110.	4700.	250.	20.	3.1	0.2	0.3	1.1	0.6	31.5	8.3	4.5	0.9	2.0	10.7	16.2	5.5	2.1	SNLO	94.00	ANWD	41
29	4.	0.5	3.	85.	5000.	390.	18.	5.6	0.1	0.3	3.0	0.5	34.3	8.0	1.5	0.9	1.2	9.2	11.3	2.1	2.8	SNLO	100.0	MMSL	[illegible]
30	12.	0.7	1.	51.	4700.	110.	20.	2.7	0.1	0.3	1.2	0.5	30.0	8.3	5.0	0.9	1.8	9.6	14.3	4.7	1.2	SNLO	54.0	BUGR	
31	11.	1.7	2.	240.	3900.	300.	25.	6.6	0.5	0.6	7.2	1.0	27.4	8.3	5.6	1.0	2.3	9.9	11.0	1.1	2.5	SNLO	100.0	BLSB	41

(1) Cation-exchange Capacity
(2) Exchangeable Sodium Percentage
(3) Permanent Wilting Coefficient
(4) Field Capacity
(5) Available Water
(6) Organic Matter
(7) Organic Matter Nitrogen Available in One Year From Sample Date
+ All Values are in ppm Available Unless Otherwise Indicated
√ See Pocket Figure 3-2-1 for Soil Types Corresponding to Soil Unit Numbers
* See Table B-2-5 for Vegetation Tables Corresponding to Vegetation Abbreviations



LEGEND

9 — HAGGA LOAM

41 — GLENDIVE LOAM

63 — RENTSAC-CHANNERY

66 — REDCREEK-RENTSAC COMPLEX

70 — PICEANCE LOAM

71C — FORELLE LOAM

75 — RIVRA LOAM

■ WOODWARD-CLYDE SAMPLING POINT

● C-b SHALE OIL SAMPLING POINT

▲ SCS SAMPLING POINT

SOIL SAMPLE LOCATION MAP

FIGURE 3-2-2

moderate (50 percent), except in those cases where organic matter is high (see above). Calcium concentrations are generally high (>4600 ppm). Magnesium values are moderate for the most part (550 ppm). Potassium is generally deficient (<100 ppm), as is zinc (ca 0.1 ppm). Sodium and manganese concentrations are moderate in most soils (100 and 6 ppm, msp). Sodium is excessive in sites supporting greasewood and big sagebrush (>1000 ppm). Copper is generally moderate (0.6 ppm), though it was deficient in one sample from a pinyon-juniper site (0.3 ppm). Sulfur (sulfate) is excessive (>650 ppm) in three samples (from sagebrush and greasewood sites), deficient in two samples (2 ppm) (pinyon-juniper and sage sites) and moderate to low (25-10 ppm) in the remaining samples. Nitrate values were high (ca 30 ppm) in most sites and excessive (possibly detrimental) in one site (pinyon-juniper) (>50 ppm). Ammonia results were identical to those of nitrate (ca 2 ppm). Boron values are moderate (0.5 ppm) in most sites and high in a pinyon-juniper site (1.0 ppm), though not at a toxic level (Table 3-2-3).

The high lime percentages in all soil samples are a possible explanation for low available phosphorus levels, as lime inhibits phosphorus availability (Brady 1974). Low phosphorus levels may also be the result of pH values in excess of 7.0. The high nitrate values suggest high soil micro-organism concentration, as do high ammonia levels. High to moderate calcium and magnesium values also favorably influence nitrates. Zinc deficiencies may be a result of high pH values, although other trace elements are not affected to the same degree. Available potassium values may be low because of the influence of the high lime concentration on micro-organisms. Lime stimulates micro-organism activity which results in the decrease of available potassium because of its absorption by the microflora.

3.2.5.3 Soil Productivity

The selected species, H. vulgare var. Briggs and A. sativa var. victory, show no difference in germination between soil types (Table 3-2-4 and Figures 3-2-3 and 3-2-4). However, both species showed greatest growth and biomass accumulation in soil types 2 and 10 (Redcreek-Rentsac Complex) (Figure 3-2-5) with less production in the other soil samples. Production was greatest in the vermiculite control (Figures 3-2-3 and 3-2-4, and Tables 3-2-5 and 3-2-6).

Soil sample 2 is significantly more productive in terms of oats and barley than is sample 10, and sample 10 is significantly more productive than samples 1 (Rentsac Loam), 3 (Forelle Loam), 4 (Glendive Loam), 5 (Rentsac Loam), and 6 (Hagga Loam) (Figures 3-2-3 and 3-2-4, and Tables 3-2-5 and 3-2-6).

Samples 1, 3, 4, 5, and 6 are essentially soil samples with low productivity and samples 2, 10, and the controls are different samples having significantly higher productivity in terms of shoot length

Table 3-2-4 GERMINATION RATE COMPARISON FOR SOIL PRODUCTIVITY TEST SAMPLES*

Germination Rate	Calc. x 2	Critical Value x 2	Decision on Null
Hordeum	2.14	14.07	Accept
Avena	3.25	14.07	Accept

*Chi square goodness of fit to test the null hypothesis that no difference in germination rates exists between soil types for Hordeum and Avena.

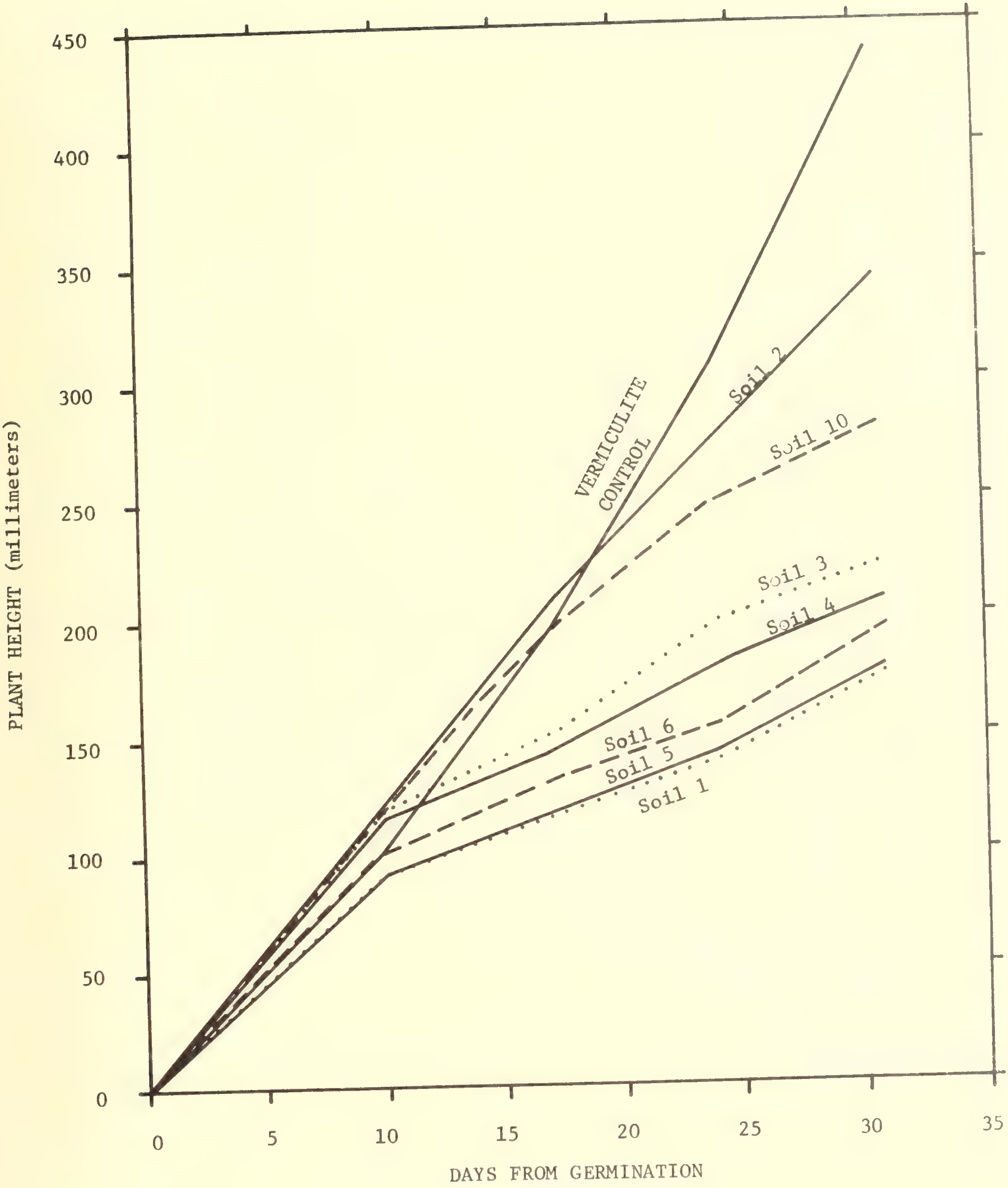


Figure 3-2-3 GROWTH OF Hordeum vulgare var. Briggs

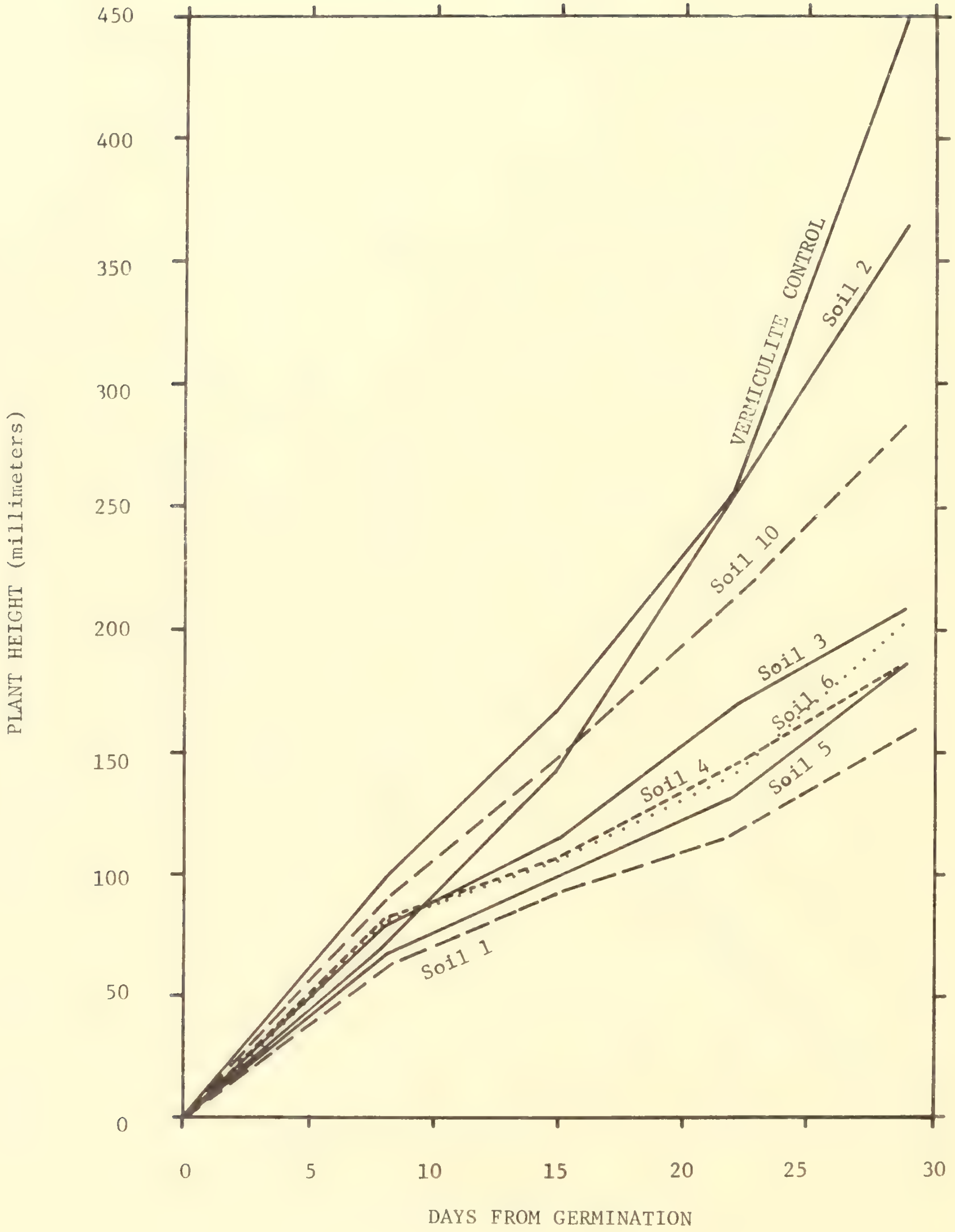


Figure 3-2-4 GROWTH OF Avena sativa var. Victory

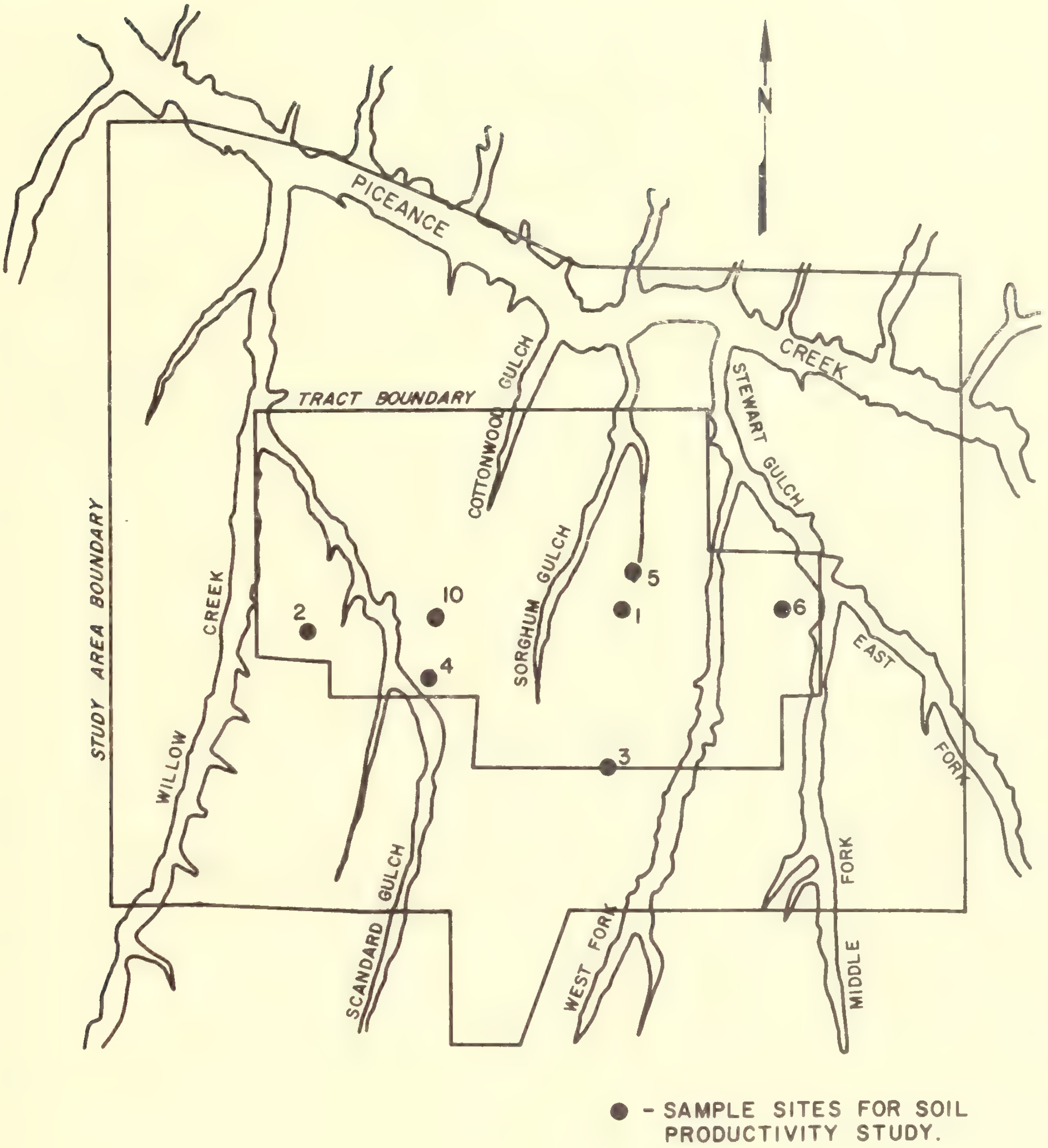


Figure 3-2-5 SOIL PRODUCTIVITY SAMPLE SITES

Productivity Assessment Sample Number	Soil Unit Name	Soil Map Symbol
1	Rentsac Channery Fine Sandy Loam	63
2	Redcreek-Rentsac Complex	66
3	Forelle Loam	71C
4	Glendive Fine Sandy Loam	41
5	Rentsac Channery Fine Sandy Loam	63
6	Rentsac Channery Fine Sandy Loam	63
10	Redcreek-Rentsac Complex	66

Table 3-2-5 MULTIPLE COMPARISONS TEST (STUDENT-NEWMAN-KEULS) FOR DIFFERENCES IN SHOOT LENGTHS BETWEEN SOIL TYPES

HORDEUM

Soil Sample	1	5	6	4	3	10	2	C
$\bar{X}$ Shoot Length	173±13	171±22	193±9	203±18	220±9	277±12	341±29	438±13
Difference	$\bar{X}_1$ =	$\bar{X}_5$ =	$\bar{X}_6$ =	$\bar{X}_4$ =	$\bar{X}_3$ ≠	$\bar{X}_{10}$ ≠	$\bar{X}_2$ ≠	$\bar{X}_C$

AVENA

Soil Sample	1	5	4	6	3	10	2	C
$\bar{X}$ Shoot Length	152±9	185±21	186±15	201±14	207±15	282±10	363±19	448±24
Difference	$\bar{X}_1$ =	$\bar{X}_5$ =	$\bar{X}_4$ =	$\bar{X}_6$ =	$\bar{X}_3$ ≠	$\bar{X}_{10}$ ≠	$\bar{X}_2$ ≠	$\bar{X}_C$

Table 3-2-6 NON-PARAMETRIC MULTIPLE COMPARISONS TESTS (ZAR 1974) FOR DIFFERENCES IN BIOMASS BETWEEN SOIL TYPES

HORDEUM

Soil Sample	5	1	6	3	4	10	2	C
$\bar{X}$ Biomass	.0255	.0267	.0297	.0384	.0387	.0573	.1234	.2184
Difference	$\bar{X}_5$ ≠	$\bar{X}_1$ ≠	$\bar{X}_6$ =	$\bar{X}_3$ =	$\bar{X}_4$ ≠	$\bar{X}_{10}$ ≠	$\bar{X}_2$ ≠	$\bar{X}_C$

AVENA

Soil Sample	1	5	3	6	4	10	2	C
$\bar{X}$ Biomass	.0221	.0271	.0317	.0322	.0328	.0542	.1110	.1424
Difference	$\bar{X}_1$ ≠	$\bar{X}_5$ ≠	$\bar{X}_3$ =	$\bar{X}_6$ =	$\bar{X}_4$ ≠	$\bar{X}_{10}$ ≠	$\bar{X}_2$ ≠	$\bar{X}_C$

growth. The biomass data tend to be slightly more complex, with the low productivity soils forming three populations. Samples 3, 4, and 6 are relatively low in productivity compared to 2 and 10, while soil samples 1 and 5 (Rentsac loam) are significantly different from each other and lower in productivity than 3, 4, and 6. Avena biomass production is lowest in soil sample 1 and Hordeum is lowest in sample 5 (Table 3-2-6). These data indicate that in terms of the bioassay the most productive soils sampled on Tract C-b are from locations 2 and 10.

No significant correlation was found between the nutrient levels occurring in the soils and the productivity of the bioassay species. However, NO_3 levels in soils 2 and 10 are three to five times higher than NO_3 levels in the other soils (Table 3-2-7). In addition, phosphorus levels, while low throughout the Tract, are relatively high in samples 2 and 10. Two additional patterns are apparent in the soil analysis data: the SO_4 levels in samples 2 and 10 are two to five times lower than the other sites; and the electrical conductivity test for salts indicates that the salt content of samples 2 and 10 is up to two times that of the less-productive soils.

No trends were noted in the other soil analysis data. All other parameters analyzed (e.g., cation-exchange capacity and soil water retention) exhibited overlapping variations in magnitude.

The relatively higher salt content and lower sulfur content of soils 2 and 10 are generally considered to be disadvantageous to plant growth. However, these conditions are apparently countered by the higher level of NO_3 and slightly increased level of phosphorus in the more productive soils. The high level of available NO_3 appears to be the most important difference between the Tract soils in the areas around soil sample sites 2 and 10 and those in the other five sites. Since the NH_4 levels are similar at most sites, larger populations of nitrifying bacteria may be present at sample sites 2 and 10, thus making increased NO_3 available for plant growth.

3.2.5.4 Soil-Vegetation Interrelationships

Correlations of soil characteristics with the four major plant communities occurring on Tract C-b have been completed. These analyses are summarized in Figure 3-2-6, which show the relative values that have been computed from actual nutrient values using a ratio. The highest value for a given nutrient in one of the five stands was set equal to 100 percent, all other values were then adjusted proportionately for nitrate-nitrogen, phosphorus, potassium, boron, calcium, copper, iron, magnesium, manganese, salts (electrical conductivity), sulfate-sulfur, zinc, pH, field capacity (-15 Bar), and percent soil moisture in relation to each of the four major plant communities in terms of shrub density per hectare and percent cover by herbaceous species.

Table 3-2-7 NUTRIENT ANALYSIS FOR SOIL PRODUCTIVITY TEST SAMPLES

Nutrients (ppm)	Soil Samples						
	1 (63)	2 (66)	3 (71C)	4 (41)	5 (63)	6 (63)	10 (66)
NO_3-N	5	27	6	10	7	7	38
NH_4-N	28	39	18	23	38	38	46
P	6	26	16	2	7	24	30
K	120	130	250	300	130	220	490
Ca	4900	2900	2600	3400	4200	2600	4100
Mg	200	380	550	230	290	410	340
SO_4-S	17	6	37	10	27	14	5
Fe	5.2	10	7.2	2.6	9.7	29	6.6
Zn	.5	.4	.5	.2	.5	3.6	1.3
Cu	.7	.3	.8	.5	.5	1.3	.7
Mn	1.0	1.9	3.7	.9	1.4	9.6	2.5
B	.5	.8	.8	.9	.5	.6	1.2
Salts $ECx10^3$	.28	.47	.27	.31	.32	.29	.58
Water – Holding Capacity, 15 BAR	11	10	14	10	16	18	17

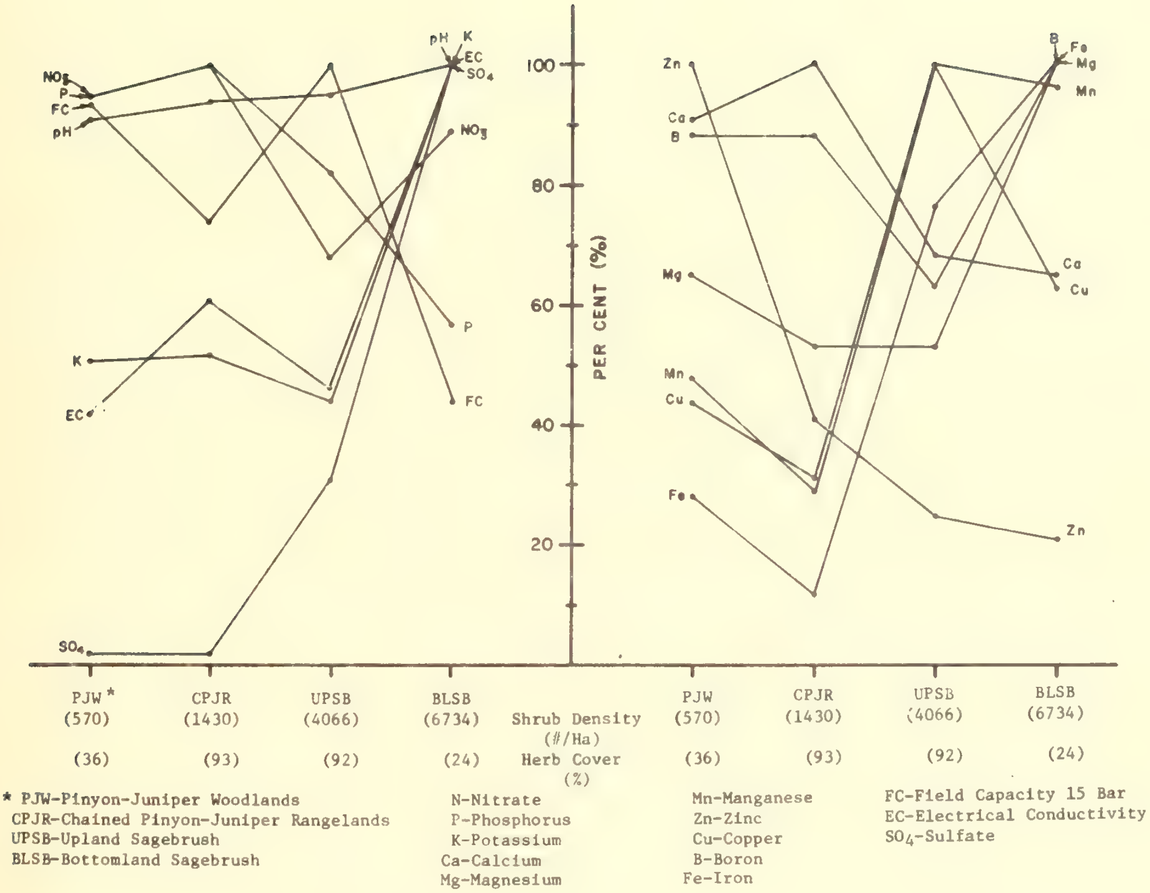


Figure 3-2-6
SOIL NUTRIENT SUMMARY FOR THE FOUR MAJOR VEGETATION TYPES IN THE TRACT C-b STUDY AREA

The analysis of these data do not reveal the presence of strong trends between vegetation type and soil characteristics. A number of important features are indicated however: 1) none of the vegetation types have high nutrient regimes; 2) all are deficient in zinc with a general trend toward decreasing zinc in sagebrush-dominated stands particularly the bottomland sites; 3) most stands are low in phosphorus and potassium, except for the high potassium values in bottomland sagebrush sites; 4) iron tends to increase in sagebrush-dominated sites; 5) pH is uniformly high; 6) total salts (EC) and sulfate increase in sagebrush-dominated sites. These general characteristics and trends point to the marked differences between woodland and range sites as a group and big sagebrush communities as another group. The high densities of sagebrush indicate a tolerance by sagebrush for high salts, low available soil water, and high pH.

Other indications (cf. Soil Productivity Studies) show that chained rangelands are the most productive sites. This has been attributed to more substantial populations of soil microorganisms in this vegetative type. An important factor in the availability of phosphorus is a neutral pH (near 7.0) which also exerts a strong influence on the activity of microorganisms (Brady 1974).

3.2.5.4.1 Interspecific Competition

Analysis of variance and correlation analysis of soil and vegetation data have been performed in order to ellucidate interrelationships between these characteristics.

Soil and vegetation data used in the analysis of variance and regression-correlation analyses are shown in Tables 3-2-8, 3-2-9, and 3-2-10. Specific methods are in Appendix IV-A, Section 2.

The A, B, C, and D Classifications identify the parameters for analysis of variance. The columns represent the observations of importance values, frequencies, and soil characteristics for each sample plot. Correlation and regression analyses were performed on all combinations of the column data. The data shown in Tables 3-2-8 to 3-2-10 have been reduced to 18 sets of samples that correspond across the vegetation and soil data for the analysis of variance. Twenty sets of observations across all data were used in the correlation and regression analyses.

3.2.5.4.1.1 Analysis of Variance

In the analysis of variance three data treatments were applied: 1) shrub importance values were compared to assess the significance of relationships between shrub species; 2) herb frequencies were compared to determine significant interrelationships between individual herb species; and 3) soil nutrients were compared to determine significant correlations in those parameters.

Table 3-2-8 CLASSIFICATION OF VARIABLES FOR ANALYSIS OF VARIANCE

SHRUB IMPORTANCE VALUES

SOILS VERSUS SHRUB IMPORTANCE VALUES

SAMPLE	SOIL	TYPE	OPPO A1	ARTR A2	SYOR A3	JUOS A4	PUTR A5	PIED A6	AMSP A7	CHNA A8			
4-4	(41)404F	BLSB	12.6	245.4	0.0	0.0	2.7	0.0	0.0	7.5	B1	C1	D1
A16	(41)16	BLSB	16.4	225.6	8.2	0.0	0.0	0.0	0.0	49.8	B2		
A19	(41)19	BLSB	7.6	261.8	0.0	0.0	0.0	0.0	0.0	30.0	B3		
5-5	(63)505F	PJWD	0.0	86.9	0.0	14.2	24.3	65.6	65.6	5.6	B1	C2	
A9	(63)9	PJWD	19.4	49.8	5.8	14.8	145.6	41.8	0.0	0.0	B2		
A13	(63)13	PJWD	0.0	14.9	113.9	4.1	23.5	11.0	34.2	4.9	B3		
2-2	(66)202F	CPJR	11.9	34.3	10.2	34.4	38.6	50.0	14.9	64.8	B1	C3	
A7	(66)7	CPJR	17.5	78.5	104.2	23.3	11.0	12.6	18.5	5.9	B2		
A10	(66)10	CPJR	6.2	124.5	9.9	16.6	86.5	28.9	9.9	9.0	B3		
3-3	(71C)303F	UPSB	23.8	234.2	0.0	2.8	0.0	16.0	16.8	5.0	B1	C1	D2
A15	(71C)15	UPSB	2.6	133.8	41.6	0.0	1.2	7.7	49.2	58.8	B2		
A11	(70)11	UPSB	24.9	235.9	2.2	7.1	0.0	21.5	2.6	0.0	B3		
1-1	(63)101F	CPJR	6.8	141.7	10.1	13.3	32.3	19.5	11.3	26.5	B1	C2	
A20	(63)20	BUGR	4.7	31.7	0.0	0.0	0.0	0.0	0.0	3.4	B2		
A21	(63)21	DGFF	0.0	0.0	106.1	16.0	0.0	11.8	0.0	0.0	B3		
6-6	(66)606F	PJWD	45.8	171.0	3.0	16.7	2.5	23.5	25.4	26.7	B1	C3	
A14	(66)14	CPJR	1.6	3.2	100.9	29.2	17.9	38.3	31.3	1.6	B2		
A12	(66)12	PJWD	28.3	113.1	14.2	7.5	5.7	49.6	35.0	0.0	B3		

TABLE 3-2-9 CLASSIFICATION OF VARIABLES FOR ANALYSIS OF VARIANCE

HERB FREQUENCIES

SOILS VERSUS HERB FREQUENCY PERCENT

SAMPLE	SOIL	TYPE	AGSM A1	FEBR A2	KOGR A3	ORHY A4	CAPE A5	SPCO A6	STCO A7	BRTE A8	PHLO A9	SILO A10			
4-4	(41)404F	BLSB	50	0	0	26	0	0	8	100	0	0	B1	C1	D1
A16	(41)16	BLSB	70	75	100	0	0	25	80	100	0	5	B2		
A19	(41)19	BLSB	10	0	0	45	0	5	0	100	0	0	B3		
5-5	(63)505F	PJWD	16	4	0	58	30	0	4	30	0	72	B1	C2	
A9	(63)9	PJWD	80	0	30	45	40	0	20	10	0	5	B2		
A13	(63)13	PJWD	60	0	45	35	0	5	50	10	0	10	B3		
2-2	(66)202F	CPJR	26	4	10	14	4	6	4	98	8	36	B1	C3	
A7	(66)7	CPJR	85	45	55	50	40	0	50	20	0	25	B2		
A10	(66)10	CPJR	55	0	40	40	0	5	50	0	0	0	B3		
3-3	(71C)303F	UPSB	100	74	100	0	88	52	22	4	98	0	B1	C1	D2
A15	(71C)15	UPSB	100	75	100	0	45	40	65	0	0	0	B2		
A11	(70)11	UPSB	100	25	100	75	50	95	30	0	0	0	B3		
1-1	(63)101F	CPJR	20	8	18	56	24	0	18	81	8	32	B1	C2	
A20	(63)20	BUGR	10	0	0	90	0	0	0	35	0	0	B2		
A21	(63)21	DGFF	0	60	30	0	40	0	0	0	0	30	B3		
6-6	(66)606F	PJWD	74	52	44	8	34	20	34	16	66	6	B1	C3	
A14	(66)14	CPJR	55	45	50	55	15	20	0	55	0	35	B2		
A12	(66)12	PJWD	80	85	65	0	55	20	70	25	0	15	B3		

Table 3-2-10 **CLASSIFICATION OF VARIABLES FOR ANALYSIS OF VARIANCE**

SOIL CHARACTERISTICS

SOIL TYPE VERSUS CHARACTERISTICS

SAMPLE NO.	NO_3 -N A1	NH_4 -N A2	P A3	K A4	Ca A5	Mg A6	SO_4 -S A7	Fe A8	Zn A9	Cu A10	Mn A11	B A12	CEC A13	pH A14	% LIME A15	SALT A16	ESP A17	PWC A18	FC A19	% AW A20	% OM A21	TEXTURE *	OMN A22	VEG TYPE	SOIL TYPE			
04	10.	0.2	2.	300.	3400.	230.	10.	2.6	0.2	0.5	0.9	0.9	25.0	8.2	6.0	0.3	2.0	10.0	23.0	13.0	3.2	SILO	128.0	BLSB	41	B1	C1	D1
16	14.	2.0	6.	130.	4600.	240.	40.	4.4	0.4	0.3	2.1	0.7	30.9	8.2	5.8	0.8	1.7	18.4	24.6	6.2	3.7	SNCLLO	120.0	BLSB	41	B2		
19	15.	1.5	2.	230.	3800.	190.	25.	4.1	0.1	0.3	1.7	0.6	25.6	8.2	3.8	1.1	2.2	11.1	17.3	6.2	2.0	SNLO	90.0	BLSB	41	B3		
05	7.	0.4	7.	130.	4200.	290.	27.	9.7	0.5	0.5	1.4	0.5	30.0	8.4	4.6	0.3	1.7	16.0	28.0	12.0	5.1	SILO	204.0	PJWD	63	B1	C2	
[illegible]	[illegible]	2.0	18.	130.	4900.	220.	20.	5.3	0.2	0.3	1.7	0.6	32.2	8.1	5.9	1.0	1.6	17.4	23.7	6.3	3.0	SNCLLO	120.0	PJWD	63	B2		
13	7.	0.8	1.	46.	4800.	190.	12.	2.0	0.1	0.2	1.0	0.4	31.5	8.3	9.0	0.7	1.4	17.2	23.1	5.9	2.3	SNCLLO	92.0	PJWD	63	B3		
02	27.	0.4	26.	130.	2900.	380.	6.	10.0	0.4	0.3	1.9	0.8	22.0	8.2	1.0	0.5	2.3	10.0	22.0	12.0	3.2	SILO	128.0	CPJR	66	B1	C3	
07	5.	0.6	8.	140.	5400.	390.	30.	1.6	0.1	0.2	0.9	0.5	37.1	8.3	8.5	0.7	1.2	18.9	25.4	6.5	2.4	SNCLLO	96.0	CPJR	66	B2		
10	12.	2.0	11.	130.	5200.	240.	5.	3.0	0.1	0.3	1.5	0.6	34.3	8.2	4.5	0.9	1.4	20.3	26.8	6.5	4.6	SNCLLO	120.0	CPJR	66	B3		
03	6.	0.2	16.	250.	2600.	550.	37.	7.2	0.5	0.8	3.7	0.8	23.0	7.8	0.3	0.3	2.6	14.0	25.0	11.0	3.6	SICLLO	126.0	UPSB	71C	B1	C1	D2
15	4.	0.5	2.	95.	4500.	580.	20.	4.5	0.6	0.5	3.0	0.5	33.2	8.1	1.3	0.7	1.1	24.7	31.2	6.5	2.4	CLLO	96.0	UPSB	71C	B2		
11	4.	0.5	2.	80.	4700.	740.	25.	2.4	0.3	0.4	1.3	0.5	35.7	8.3	5.9	0.8	1.1	25.4	32.7	7.3	2.3	SICLLO	92.0	UPSB	70	B3		
01	5.	0.3	6.	120.	4900.	200.	17.	5.2	0.5	0.7	1.0	0.5	33.0	8.5	4.6	0.3	1.5	11.0	23.0	12.0	2.8	SNCLLO	112.0	CPJR	63	B1	C2	
20	9.	0.7	2.	100.	3100.	180.	25.	3.2	0.1	0.3	1.4	0.6	21.4	8.5	5.1	1.1	4.7	8.6	10.4	1.8	1.4	SILO	63.0	BUGR	63	B2		
21	5.	1.1	14.	79.	5600.	280.	30.	7.0	0.1	0.3	2.5	0.6	37.2	8.1	7.6	0.9	1.9	14.7	20.3	5.6	4.3	SNLO	120.0	DGFF	63	B3		
06	7.	0.4	24.	220.	2600	410.	14.	29.0	3.6	1.3	9.6	0.6	21.0	7.2	0.8	0.3	1.9	18.0	33.0	15.0	6.2	SICLLO	217.0	PJWD	66	B1	C3	
14	7.	1.3	9.	89.	6100.	390.	18.	3.0	0.4	0.3	1.5	0.6	41.1	8.2	7.4	0.8	1.1	19.3	25.6	6.3	3.5	SNCLLO	120.0	CPJR	66	B2		
12	7.	0.9	6.	93.	4900.	370.	25.	4.4	0.1	0.3	1.3	0.6	33.7	8.2	7.3	0.8	1.2	17.8	24.0	6.2	2.4	SICLLO	96.0	PJWD	66	B3		

* SI Silt
LO Loam
SN Sand
CL Clay

Analysis of variance was performed on the three sets of data shown in Tables 3-2-8 through 3-2-10. The purpose was to identify significant interactions between the four parameters of the matrix classifications. Their parameters are: A) species or soil characteristics; B) the variations within similar soil types and vegetative communities; C) the variations between soil types and vegetation communities; and D) variation between two sets of similar observations. The results of these analyses are summarized in Table 3-2-11 for Shrub Importance Values, Herb Frequencies, and Soil Characteristics. The significant classification parameters and interactions are a function of the F-Ratio and degrees of freedom. These are shown in the table with asterisks on values significant at the 5 percent level. Parameters A and C and interaction AC are identified as significant contributors to the total variance for shrub importance values and herb frequency. Parameter B and interaction AB were identified as a significant contribution to the variance in the soil characteristics analysis, Table 3-2-11. This means the soil characteristics (chemical analyses) did show differences within the soil type and vegetation community classifications. A close examination of Table 3-2-10 shows several trends in the data and suggests a definite pattern associated with the sample order number. The sample numbers were ordered from low to high in each soil type.

3.2.5.4.1.2 Correlation and Regression Analysis

A multiple linear regression program was performed by computer to generate simple and partial correlations and regression analyses. Analyses performed correlated shrub species with shrub species, herb species with herb species, soil characteristics with soil characteristics, and each of the vegetation species with each soil characteristic. A typical computer output is shown in Appendix IV-B, Section 2. The results of the soil and vegetation correlation analyses have been ordered into seven categories of correlation implying significant interrelationships: 1) soil characteristic-to-soil characteristic; 2) shrub species-to-shrub species; 3) herb species-to-herb species; 4) soil characteristic-to-shrub species; 5) herb species-to-soil characteristic; 6) shrub species-to-shrub species-to-soil characteristic; and 7) herb species-to-herb species-to-soil characteristic.

3.2.5.4.1.2.1 Soil-to-Soil Correlations

Soil characteristics which correlate at 95 percent and 90 percent levels of confidence are listed in Table 3-2-12. This correlation category is the largest of the seven groups segregated for interpretation, although a number of the correlations are those which would be considered tacit, such as the correlation between percent organic matter and percent organic matter available from decomposition in one year's time from sampling. Many of the correlations seen in Table 3-2-12 are redundant in that they reflect conditions produced by nutrients which also act in a similar manner in compounds or because certain

Table 3-2-11 F-RATIOS FOR ANALYSIS OF VARIANCE

Factor	Shrub Importance Value	Herb Frequency	Soil Characteristics
A	26.34*	4.66*	405.21*
B	0.40	0.62	3.59
AB	1.57	1.02	4.57*
C	2.02	5.99*	0.51
AC	8.16*	1.34	1.03
BC	0.30	0.51	1.93
ABC	--	--	--
D	0.77	5.68*	0.05
AD	0.62	2.18*	0.13
BD	0.79	3.52*	0.55
ABD	--	--	--
CD	0.72	3.10*	0.12
ACD	--	--	--
BCD	--	--	--
ABCD	--	--	--
3 & 4 FACTOR INTERACTIONS			
Sum of Squares	81315.08669	82737.90777	9664722.999
Degrees of Freedom	88	112	256
Mean Square	924.035076	738.731319	37752.82421

*Significant F-Ratio at 5 percent level of significance.

Table 3-2-12 SOIL-SOIL NUTRIENT CORRELATIONS r=.42

Positive Correlations			Negative Correlations		
CEC-Ca	.97		%AW-Salt	.91	
Mn-Zn	.94		pH-Mn	.90	
Zn-Fe	.94		pH-Zn	.82	
Mn-Fe	.92		pH-Fe	.79	
%OMN-%OM	.92		FC-ESP	.78	
Cu-Zn	.87		pH-Cu	.72	
Mn-Cu	.84		PWC-ESP	.65	
Cu-Fe	.82		pH-P	.64	
FC-PWC	.82		%Lime-Cu	.64	
%OMN-%AW	.74		%OM-pH	.63	
%OM-Fe	.73		Ca-K	.61	
%AW-Cu	.69		%Lime-Mn	.60	
%Lime-Ca	.68		%OMN-pH	.60	
Fe-P	.68		%OMN-Salt EC	.59	
Salt EC-NH4	.68		FC-Salt EC	.59	
%AW-Mn	.65		Salt EC-Cu	.58	
B-K	.66		%Lime-Fe	.58	
%OM-Zn	.65		PWC-K	.57	
%OM-Mn	.64		CEC-K	.56	
%OM-P	.62		PWC-B	.56	
ESP-K	.62		%AW-NH4	.56	
%Lime-CEC	.62		Cu-Ca	.55	
PWC-CEC	.61		%AW-%Lime	.55	
%AW-Fe	.60		B-Ca	.55	
%OM-Cu	.59		%AW-pH	.54	
%OM-%AW	.58		CEC-B	.54	
%AW-Zn	.58		%Lime-P	.52	
Mn-P	.58		%Lime-Zn	.52	
%Lime-pH	.56		Fe-Ca	.51	95% C.I.
PWC-Mg	.55		FC-pH	.49	90% C.I.
%AW-FC	.54		CEC-Fe	.49	
FC-Mg	.53		Mn-Ca	.48	
PWC-Ca	.52		Cu-NH4	.47	
Zn-P	.52		CEC-Cu	.47	
ESP-Salt EC	.51	95% C.I.	ESP-Ca	.46	
%AW-P	.48	90% C.I.	ESP-CEC	.46	
FC-Mn	.46		%OM-Salt EC	.45	
P-NO3	.46		Salt EC-Zn	.44	
Ca-NH4	.44		Zn-Ca	.43	
B-NO3	.43		CEC-Mn	.43	
FC-Cu	.43		%OMN-%Lime	.42	
Cu-P	.42				
Salt EC-%Lime	.42				
%OMN-PWC	.42				

nutrients produce similar influences on a number of other nutrients. For example, high levels of calcium will inhibit the availability of trace elements, such as iron, copper, and manganese; high lime concentrations ($CaCO_3$) have a similar effect on these trace elements.

The biologically significant correlations are those found between vegetation and the following soil constituents: 1) major soil nutrients - N, P, K, Ca, Mg, and SO_4; 2) minor soil nutrients - Fe, Mn, Cu, Zn, and B; and 3) other characteristics - available water, salts, pH, % lime, sodium, and organic matter (Table 3-2-12).

The two important features of soil productivity brought out in the soil-to-soil interactions are 1) inhibitory interactions that establish limiting soil nutrient factors and 2) the controlling influence of toxic soil constituents.

The inhibitory influence of calcium, lime, and pH on phosphorus and potassium is a strong indication that these major nutrients may be severely limiting to vegetative productivity in most sites. This factor undoubtedly also establishes the competitive structure between important shrub and herb species throughout the various plant community types (Waisel 1972). The equally inhibitory effect of calcium, lime, and pH on important trace elments--Cu, Zn, Mn, and Fe--is ample indication that the lack of these nutrients is limiting and may act as a control in species competition.

Soil moisture regimes are of major importance to vegetative production, and are important in determining toxic soil environments. The high positive correlations between available water and trace elements and several major nutrients are good indications of this interaction. Conversely, the negative correlations between available water and high levels of salts, hydrogen ions (pH), sodium, and lime show the potentially inhibitory influence of low soil water regimes. Low water regimes of the study area correlate with low levels of potassium, most trace elements, high salt levels, and low organic material concentrations, as well as higher pH.

3.2.5.4.1.2.2 Shrub to Shrub Correlations

Correlations between shrub species at a 90 percent level of confidence are shown in Table 3-2-13. The significance of these correlations lies in the implications they make regarding shrub species competition and the tolerances of shrub species in general. As will be seen, below, the negative correlations between species are not only evident from the absence of certain species associations revealed in vegetation stand sampling, but are also correlated through the nutrient/toxic element regimes in the areas where species are either conspicuously absent or predominant (Figure 3-2-7). The negative correlations between big sagebrush (Artemisia tridentata),

Table 3-2-13 SHRUB-SHRUB CORRELATIONS r=.42

Positive Correlations			Negative Correlations		
PIED-JUOS *	.63		SYOR-ARTR	.55	95% C.I.
AMSP-PIED	.57	95% C.I.	JUOS-ARTR	.43	90% C.I.
ARTR-OPPO	.49	90% C.I.			
PIED-PUTR	.46				

*Species Abbreviations:
ARTR = *Artemisia tridentata*
AMSP = *Amelanchier* spp.
JUOS = *Juniperus osteosperma*
OPPO = *Opuntia polyacantha*
PIED = *Pinus edulis*
PUTR = *Purshia tridentata*
SYOR = *Symphoricarpos oreophilus*

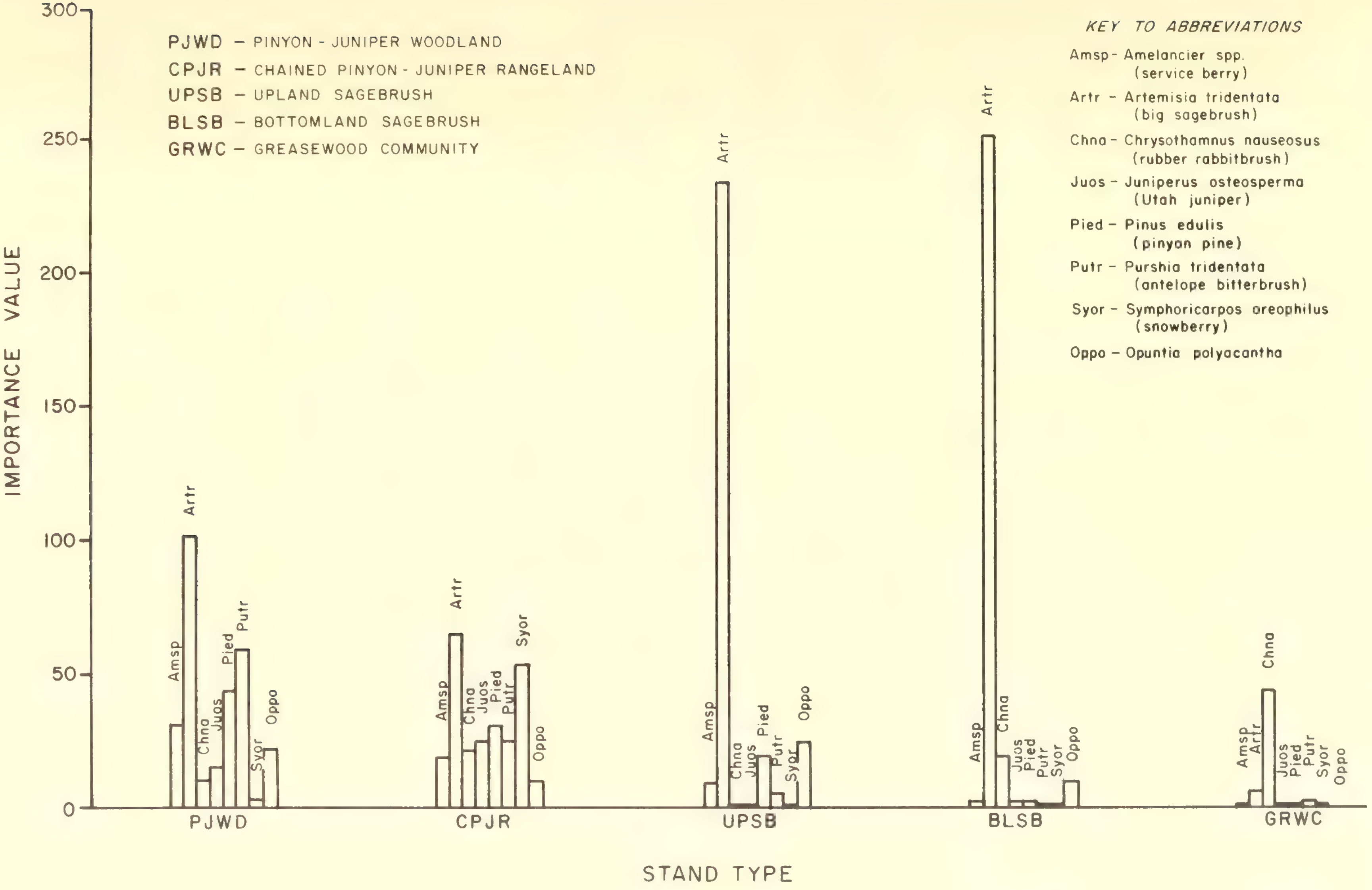


FIGURE 3-2-7 COMPARISON OF IMPORTANCE VALUE
FOR SEVEN IMPORTANT SHRUB SPECIES
IN FIVE STAND TYPES IN THE TRACT C-b STUDY AREA

and both snow berry (Symphoricarpos oreophilus) and juniper (Juniperus osteosperma) bear out this observation. The positive correlations between other species are reflected in the strong associations between these species in the results of vegetation stand sampling.

3.2.5.4.1.2.3 Herb to Herb Correlations

The correlations between herbaceous species (Table 3-2-14) contributes in a like manner to the competitive relationships between species and between species and soil environments. Notable among these are the negative correlations between cheatgrass (Bromus tectorum) and two important perennial grasses, western wheatgrass (Agropyron smithii) and june grass (Koleria gracilis). The two perennial species are predominant in undisturbed upland sites, but are relatively sparse or absent on lowland soils and on disturbed soils in general. Both lowland soils and disturbed sites show high densities of cheatgrass. The negative correlation between the perennial grasses and cheatgrass reflects the aggressive nature of the annual, as well as the low tolerance of the perennial grasses to salty, high pH soil environments. These facts are borne out by community sampling data; the actual mechanism involved, however, is related in the opposing correlations of the perennials and cheatgrass. Cheatgrass appears to be suitably tolerant of very high nitrate and potassium concentrations, unlike the perennial grasses. The fact that cheatgrass can grow in abundance in toxic soil environments may actually be the result of the seasonal changes in soil moisture interacting with high salts and other toxic substances. During the spring, when soil moisture is high, the concentrations of toxic substances, which are abundant in lowland soils, are potentially significantly less than during the summer seasons low moisture regime. Since cheatgrass germinates and sets seed early in the season it effectively avoids the influence of toxic substances (Youngner and McKell 1972).

Positive herb to herb correlations are also reflected in sampling data (Figure 3-2-8) such as those between western wheatgrass and june grass and between sedge and phlox. The overall significance between groups of species which have positive correlations is that they reflect the way in which species associate in community types; and further that the influences of soil nutrients on these assemblages is strongly indicated.

3.2.5.4.1.2.4 Soil to Shrub Correlations

There are few correlations between soils and shrubs at the 90 percent level of confidence (Table 3-2-15). No obvious patterns of soil nutrient/toxicity regimes are apparent from the correlation results. At lower levels of statistical confidence, however, there appear to be correlations between soil moisture values and most species, and negative

Table 3-2-14 HERB-HERB CORRELATIONS r=.42

Positive Correlations		
KOGR-AGSM *	.80	
SPCO-KOGR	.74	
KOGR-FEBR	.70	
STCO-KOGR	.68	
STCO-AGSM	.63	
SPCO-AGSM	.63	
CAPE-FEBR	.61	
CAPE-KOGR	.58	
PHLO-CAPE	.55	
STCO-FEBR	.55	
SPCO-CAPE	.54	
CAPE-AGSM	.54	95% C.I.
AGSM-FEBR	.47	90% C.I.
SPCO-FEBR	.44	

Negative Correlations		
BRTE-CAPE	.62	
ORHY-FEBR	.57	95% C.I.
BRTE-KOGR	.47	90% C.I.
SILO-AGSM	.46	
BRTE-AGSM	.44	

*Species Abbreviations:

AGSM = *Agropyron smithii*
BRTE = *Bromus tectorum*
CAPE = *Carex pensylvanica*
FEBR = *Festuca brachyphylla*
KOGR = *Koleria gracilis*
ORHY = *Oryzopsis hymenoides*
PHLO = *Phlox longifolia*
SILO = *Sitanion longifolium*
SPCO = *Sphaeralcea coccinea*
STCO = *Stipa comata*

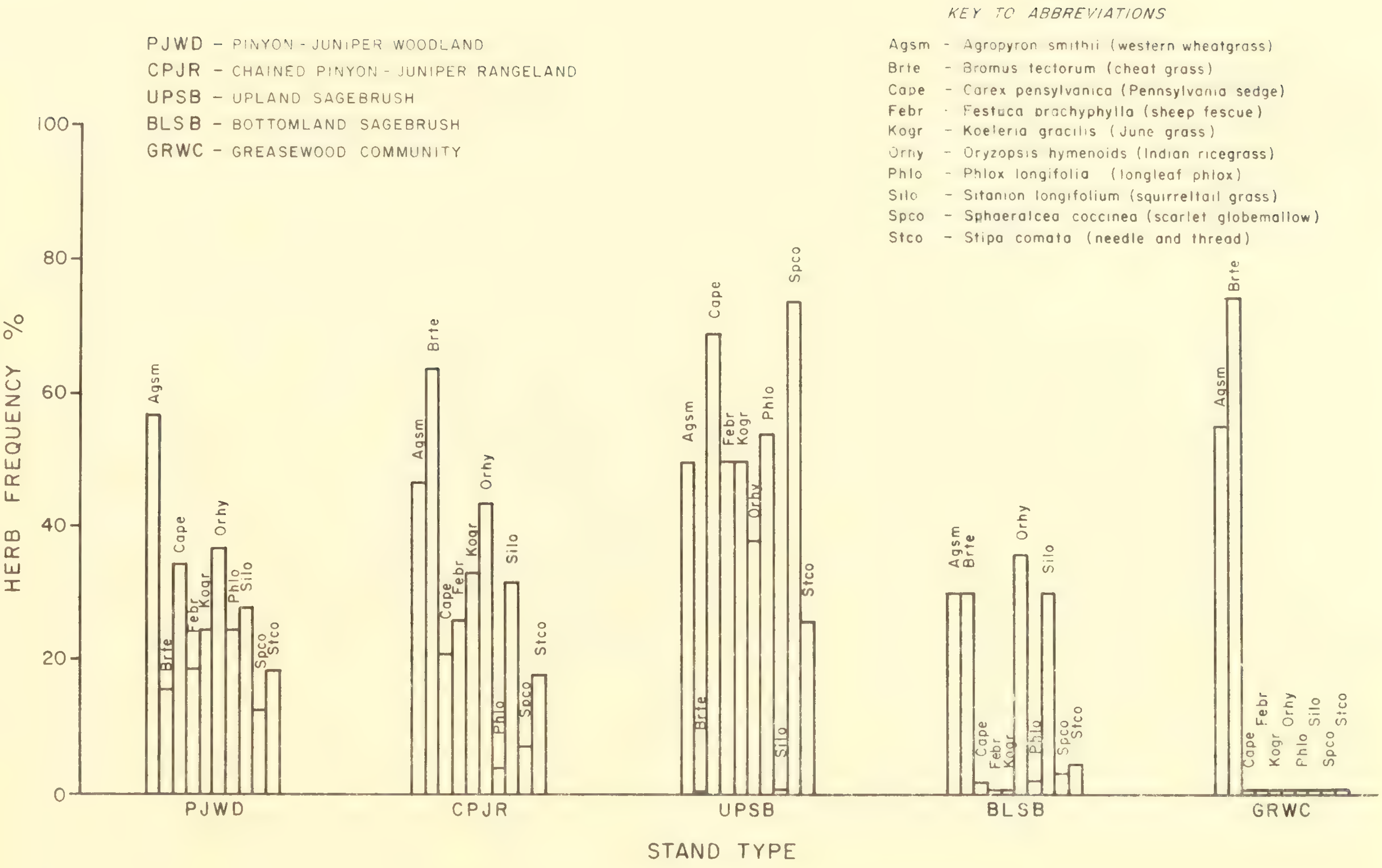


FIGURE 3-2-8 COMPARISON OF FREQUENCY VALUE
FOR TEN HERBACEOUS SPECIES
IN FIVE STAND TYPES IN THE TRACT C-b STUDY AREA

Table 3-2-15 SIGNIFICANT CORRELATIONS BETWEEN SPECIES AND SOIL CHARACTERISTICS 90% CONFIDENCE INTERVAL

Soil Characteristics

		NO_3	NH_4	P	K	Ca	Mg	SO_4	Fe	Zn	Cu	Mn	B	CEC	pH	%LIM	SALT	ESP	PWC	FC	%AW	%OM	OMH
Shrub Species	OPPO			.41		-.32	.38		.54	.62	.56	.61			-.68		-.33*			.49	.43		.31
	ARTR										.32*						-.34*			.41	.37		
	SYOR		.65		-.32	.46					-.24*			.39			.23*	-.32	.40		-.38	.31	
	JUOS			.44	.41	.40					.09*			.44			-.15*	-.45		.43		.43	
	PUTR	.50	.48	.39			-.31	-.38			-.18*												
	PIED			.48	-.30						.03*						-.31	-.35		.34	.36	.39	.50
	AMSP	-.33	-.36								.18*		-.32				-.43	-.33	.30	.42			.44
	CHNA	.41				-.36					.13*					-.48							
Herb Species	AGSM						.66												.66	.56			
	FEBR						.48	.47							-.46				.42				
	KOGR						.65											-.44	.78	.63			
	ORHY														.42								
	CAPE	-.42					.65												.42	.48			
	SPCO						.86												.57	.52			
	STCO																	-.43	.60	.47			
	BRTE	.48			.45		.41						-.53						-.63	-.45			
	PHLO			.52		-.59			.59	.58	.76	.70		-.49	-.72	-.62	-.49				.50	.42	.43
	SILO																						.48

*Very high t - value

correlations between many species and toxic soil constituents. In general, however, the direct correlations between soil constituents and shrubs are not strong. This lack of statistical correlation should not be wholly interpreted as a lack of relationship between these parameters. These parameters must be compared on a site to site basis in terms of the many individual positive and inhibitory interactions taking place rather than in terms of the more broad environmental gradients on which this approach has based its considerations.

3.2.5.4.1.2.5 Soil to Herb Correlations

These correlations are also somewhat weak at the 90 percent level of statistical confidence (Table 3-2-15), although the positive correlation between many species and the soil water regime is apparent at this level. Lower levels of confidence improve interpretive insight initiated at the 90 percent level. The negative correlations between most species and toxic substances are of importance. Also of interest is the negative correlation of several important perennial grasses to both NO_3^- and NO_4^-. This is an indication of the oversupply of these substances in certain communities--such as bottomland sagebrush and greasewood stands--where perennial grasses are sparse or absent. Converse to this is the positive correlation of cheatgrass to these substances and this species' negative correlation with available water. Another set of important correlations is the negative correlation between both western wheatgrass and junegrass and pH, as compared to the positive correlation between Indian ricegrass and higher pH.

The correlations between herbs and soils are poorly developed for the most part, however, so that the same reservations suggested for making interpretations of soil-shrub correlations should be employed.

3.2.5.4.1.2.6 Shrub to Shrub to Soil Correlations

Comparisons of correlated species of shrubs and the soil correlations (simple and partial) shared between given pairs of shrub species are shown in Table 3-2-16. Although many of the species listed in Table 3-2-16 correlate with major nutrients and trace elements and with available water and other indications of water regimes, and correlate negatively with toxic elements such as salts, pH, and sodium; the cross-correlations between species pairs and soil constituents are predominantly found in four areas: 1) macro and micro nutrients Ca, P, K; Cu, Fe, and Mn; 2) the toxic indicators Salts-EC and E.S.P.; 3) the water regime indicators field capacity and available water; and 4) organic matter content of soils and cation exchange capacity. These cross-correlations are important because they serve as some indication of the level at which species are correlated positively or negatively through the influence or direct action of some limiting or controlling factor. In this way

Table 3-2-16 CORRELATIONS BETWEEN SHRUB SPECIES PAIRS AND CORRELATED SOIL CONSTITUENTS
(75 PERCENT CONFIDENCE INTERVAL)

SOIL CHARACTERISTIC	CORRELATION TYPE	Correlated Species Pairs																					
		(+)		( )		(-)		(-)		(+)		(+)		(+)		(+)		(-)		—			
		ARTR*	OPPO	ARTR	JUOS	ARTR	PUTR	ARTR	PIED	AMSP	PIED	JUOS	PIED	JUOS	PUTR	JUOS	SYOR	OPPO	SYOR	PIED	[illegible]	[illegible]	[illegible]
[illegible]	SIMPLE											.44	.48	.44	.39					[illegible]			
	PARTIAL			-.49	.79	-.49	.53	-.49	.38			.79	.38	.79	.53	.79	.46			.38	[illegible]	[illegible]	.46
[illegible]	SIMPLE											-.41	-.30			-.41	[illegible]						
	PARTIAL																						
Ca	SIMPLE															.40	.46	-.32	.46				
	PARTIAL															.36	.57						
[illegible]	SIMPLE	.32	.56																				
	PARTIAL	.58	.45	.58	-.54	.58	.44							-.54	.44	.54	-.79	.47	-.79			.58	.79
[illegible]	SIMPLE															.44	[illegible]						
	PARTIAL	-.40	-.37	-.40	.34													-.57	[illegible]			[illegible]	[illegible]
SALI- [illegible]	SIMPLE	-.34	-.33					-.34	-.31	-.43	-.31												
	PARTIAL	.24	.32															[illegible]	-.43				
[illegible]	SIMPLE									-.33	-.33	-.45	-.35										
	PARTIAL																			-.35	-.35		
[illegible]	SIMPLE															.37	[illegible]	.29	.40				
	PARTIAL																						
	SIMPLE	.41	.49	.41	.43			.41	.34	.42	.34	.43	.34										
	PARTIAL																						
[illegible]	SIMPLE	.37	.43					.37	.36	.29	.36							.42	-.38			[illegible]	-.38
	PARTIAL																						
[illegible]	SIMPLE									.29	.39	.43	.38			.43	.31						
	PARTIAL																						
[illegible]	SIMPLE									.44	.50	.33	.50										
	PARTIAL	-.31	.54					-.31	.51	.70	.51												
[illegible]	SIMPLE																						
	PARTIAL									.35	.66							.33	.48				
[illegible]	SIMPLE																						
	PARTIAL											-.55	-.72	-.55	-.40	-.55	-.60			-.72	-.40		
[illegible]	SIMPLE																						
	PARTIAL																			.37	.55		

*ARTR = *Artemisia tridentata*
AMSP = *Amelanchier spp.*
JUOS = *Juniperus osteosperma*
OPPO = *Opuntia polyacantha*

PIED = *Pinus edulis*
PUTR = *Purshia tridentata*
SYOR = *Symphoricarpos oreophilus*

these correlations can act as indicators for soil conditions which are predominant in given community types. Figure 3-2-7 illustrates how shrub species vary in importance value in the important vegetation types on Tract C-b. This figure graphically reinforces the above discussion relative to species tolerances and competitive interactions. For example, species such as big sagebrush correlate positively with soil features typical of bottomland areas. These soil characteristics include high pH, trace elements, and salts; all of which tend to decrease the availability of macro nutrients. On upland sites where toxicity is less, other species appear to compete better with big sagebrush. This interspecific competition is clearly the result of the more adequate nutrient regimes in the lower-toxic soils of the uplands.

3.2.5.4.1.2.7 Herb to Herb to Soil Correlations

The simple and partial correlations between herbaceous species pairs and soil constituents are grouped in Table 3-2-17 into three major areas: 1) macro and micro nutrients; 2) toxic substances or conditions; and 3) soil water regime parameters.

In the first group--macro nutrients--it is significant that many of the important grass and forbaceous species are negatively correlated with NO_3; a condition which indicates an oversupply of this nutrient in certain plant communities. Reference to field data on soil nutrients and plant community herb composition indicate that these are bottomland sagebrush communities, greasewood stands, and upland sagebrush stands (the latter in only a few instances). In this respect it is important to note that western wheatgrass (Agropyron smithii) is the only perennial grass which does not correlate negatively with NO_3; western wheatgrass is also the major grass species present in the relatively dense herb layer of the upland sagebrush communities. It is equally noteworthy that cheatgrass, which is a major constituent of the herb layer in bottomland sagebrush stands and greasewood stands, is positively correlated with NO_3 concentrations. This implies a tolerance for NO_3; this tolerance may, like other toxic soil constituent levels tolerance, be by avoidance, since cheatgrass germinates and matures under early seasonally moist conditions when a greater percentage of toxic substances are in more dilute concentrations or are under the influence of leaching.

Negative correlations with the micro nutrients, Fe and Zn, may be an indication of decreased phosphate availability caused by these elements. In the toxic substances group it is seen that many of the important grasses and forbs are negatively correlated with these soil constituents. Sodium exchange and electrical conductivity are of particular interest, along with pH. The correlations of Indian ricegrass with pH is of interest; this species also demonstrates other indications of its tolerance for toxic soil environments, such as high salt regimes.

Table 3-2-17 CORRELATIONS BETWEEN HERB SPECIES PAIRS AND CORRELATED SOIL CONSTITUENTS
(75 PERCENT CONFIDENCE INTERVAL)

SOIL CHARACTERISTIC	CORRELATION TYPE	Correlated Species Pairs																																	
		(+)		(+)		(+)		(+)		(+)		(+)		(+)		(+)		(+)		(+)		(+)		(+)		( )		–							
		AGSM*	[illegible]	AGSM	KOGR	AGSM	CAPE	AGSM	STCO	FEBR	KOGR	FEBR	CAPE	FEBR	SPLO	FEBR	STCO	KOGR	SPCO	KOGR	STCO	CAPE	SPCO	CAPE	PHLO	AGSM	BRTE	AGSM	STLO	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	S									-.40	-.33	-.40	-.42	-.40	-.32			-.33	-.32			-.42	-.32										.48		
	P																																		
NH_4	S																							-.36	-.38										
	P													-.40	.41															-.40	[illegible]				
K	S																			-.36	-.31												[illegible]		
	P																	-.62	-.64			-.37	-.64									-.62			
[illegible]	S	[illegible]	.48	.66	.65	.66	.65			.48	.65	.48	.65	.48	.86			.65	.86			.65	.86	.65	.34	.66	[illegible]					.65	.41	.65	.41
	P			[illegible]	.64	.60	[illegible]	.60	.42									.64	.90	.64	.42	.49	.90			[illegible]	-.35					.64			
[illegible]	S											.47	.35																						
	P									.59	.50	.59	.41											.41	.40										
[illegible]	S																							.34	.76										
	P									.55	.42							.41	.46	.41	.38	.56	.46	.56	.58										
[illegible]	S																													[illegible]	-.38				
	P																														.63	.42			
[illegible]	S	[illegible]	-.46			-.32	-.38					-.46	-.38											-.38	-.72					-.46	.42				
	P		-.66	-.88	-.42	.88	-.54			-.66	-.42	.66	-.54											-.54	-.74	-.88	.36	-.88	.50	.66	[illegible]				
Al	S																							-.33	-.49										
	P	[illegible]	[illegible]	[illegible]	-.62	[illegible]	-.46			-.65	-.62	-.65	.46											-.46	[illegible]	-.33	.40	[illegible]	-.44			-.62	[illegible]	[illegible]	
[illegible]	S									-.31	-.44	-.31	-.31			-.31	-.43			-.44	-.43														
	P			.68	[illegible]	.68	[illegible]											.45	.42			-.39	.42	-.39	[illegible]			.68	-.47						
[illegible]	S																															[illegible]	[illegible]		
	P													.53	.51																				
[illegible]	S																																		
	P		[illegible]	.60	.43					[illegible]	.43			.47	.32											.60	.41			.47	-.31	.43	[illegible]		
[illegible]	S																																		
	P		[illegible]			-.53	[illegible]					-.31	.40															-.53	-.39						
[illegible]	S																																		
	P	[illegible]	-.66			[illegible]	-.44	-.59	.41							-.29	.41			-.66	.41							-.59	[illegible]						
[illegible]	S																																		
	P							.44	-.39																	.44	.40							-.44	[illegible]
[illegible]	S																																		
	P													.41	.36	.41	-.36													[illegible]	[illegible]				
[illegible]	S	[illegible]	[illegible]	.66	.78	.66	.42	[illegible]	.60	.42	.78	.42	.42	.42	.57	.42	.60	.78	.57	.78	.60	.42	.57			.66	-.63								
	P																																		
[illegible]	S			.56	[illegible]	[illegible]	.48	.56	.47									.63	.52	.63	.47	.48	.52			.56	-.45					.63	[illegible]	[illegible]	.45
	P																																		

*AGSM = *Agropyron smithii*
BRTE = *Bromus tectorum*
CAPE = *Carex pensylvanica*
FEBR = *Festuca brachyphylla*
KOGR = *Koeleria gracilis*

ORHY = *Oryzopsis hymenoides*
PHLO = *Phlox longifolia*
STLO = *Sitanion longifolium*
SPCO = *Sphaeralcea coccinea*
STCO = *Stipa comata*

✓ S = Simple
P = Partial

The largest number and strongest correlations between species pairs and soil constituents is in the soil water regime group. All of the perennial grasses and forb species, with the notable exception of Indian ricegrass, correlate positively with water regime parameters. Species which are commonly associated in the herb layer also cross-correlate well with these parameters. Cheatgrass correlates negatively with field capacity and also with two important perennial grasses--june grass and western wheatgrass. Cheatgrass does, however, correlate positively with permanent wilting coefficient values, as do other major species. Figure 3-2-8 illustrates how herbaceous species vary in different plant communities.

3.2.5.4.1.2.8 Conclusions

The analysis of variance and regression/correlation analyses performed on data collected from soils, important shrub and herbaceous species in 24 sites on Tract C-b illustrate the importance of several limiting or controlling factors in the soil environment when viewed from the aspect of species distributions. These analyses also imply the importance of interspecific competition, species tolerances, and tolerance by seasonal avoidance of toxic or water-limited environmental conditions. The statistical relationships at high levels of confidence (i.e., greater than 90 percent) are not strong enough to base a total scheme of year-to-year environmental trends or changes as the result of disturbance potentially owing to the development of oil shale reserves. However, the implications at lower levels of statistical confidence are adequate indicators of species interactions and correlations with soil constituents which can be used as early warning indicators of change which will have a good probability of lying outside of the realm of natural environmental trends.

The most significant indication of trends between species and soil constituents lies in five groupings of soil constituents: 1) major nutrients which may act as limiting factors because of low concentrations in most soils; 2) major nutrients which may act as controlling factors owing to their oversupply in some soils, and which interact with soil water regimes so that their toxicity occurs seasonally in some sites; 3) important trace elements which may act as limiting factors owing to their deficiencies in many areas, and which are made low or deficient because of the action of other soil substances which decrease the trace element availability; 4) toxic substances which exert strong controlling influences on the distribution of species types throughout different community types and which confer competitive advantage on more tolerant species; and 5) soil water regime parameters which interact significantly to determine the concentrations of toxic materials in plant community types both on an overall environmental basis and also through seasonal effects of fluctuating soil water levels.

For the most part, the interaction of species pairs through their correlation with soil constituents serves to reinforce the species associations that have been shown in the community sampling data derived from terrestrial vegetation studies. The correlation of species pairs through soil constituents does in some ways, however, help to explain the soil environmental influences on species associations and to aid in the understanding of association or the lack of association in the various community types of Tract C-b. This is also true of simple species correlations.

In a similar manner the correlations between soil constituents themselves simply bear out known interactions between soil nutrients and between physical characteristics of soils and soil chemistry. The species relationships seen in the Tract C-b soils data have potential in directing monitoring programs relative to soil productivity on this specific site.

3.2.5.5 Soil Biotic Studies

3.2.5.5.1 Soil Fungi

Soil fungi are the most versatile and persistent of soil microorganisms in their ability to decompose a wide range of organic residues, such as cellulose, starch, lignin, proteins, and sugars. Soil fungi may be even more important than bacteria with respect to the process of humus formation and aggregate stabilization in certain soils. They cannot oxidize ammonium compounds to nitrates as some bacteria do and they cannot fix atmospheric nitrogen. However, soil fertility is dependent on their presence since they are able to sustain the decomposition process when bacteria and actinomycetes alone are not sufficient (Buckman and Brady 1969).

The greatest number of soil fungi are found in surface layers where organic matter is abundant and aeration is adequate. Although they develop well in acid, neutral or alkaline soils they are noticeably abundant in acid soils where bacteria and actinomycetes are less abundant. The number of fungi per gram of dry soil fluctuates greatly with soil conditions and season; 10-20 million represents an approximate average (Buckman and Brady 1969). The number of fungi per gram of soil on Tract C-b was much lower than these values, ranging from 5,000-135,000 and was also appreciably lower than the number of bacteria and actinomycetes per gram (Tables 3-2-18 and 3-2-19). These values may reflect the generally low amount of humus present in soils on Tract C-b and the relatively high pH's recorded (7.2-8.5).

The number of soil fungi per gram of soil varied substantially between samples taken from beneath the shrub overstory and samples taken from open and bare ground (Tables 3-2-18 and 3-2-19). In general, values for soil taken from beneath the shrubs were higher than values for open ground. This difference is apparently related to higher amount of humus and less compaction of soils beneath major shrub

Table 3-2-18 THE ABUNDANCE OF SOIL MICROORGANISMS ON GRIDS 1 AND 2, AUGUST 1975

Sample	Total Bacteria Colonies/Gram	X̄ ± SD	Actinomycetes Colonies/Gram	X̄ ± SD	Nitrifiers Present	% of Total Showing Denitrification	Fungi Colonies Gram	X̄ ± SD
Grid 1								
Cercocarpus								
Replicate A	8,150,000		680,000		+	90	67,000	
Replicate B	2,040,000	5,396,666	290,000	556,666	+	88	257,000	112,333
Replicate C	6,000,000	±3,099,360	700,000	±231,157	+	68	33,000	±102,295
Open								
Replicate A	11,950,000		800,000		+	93	26,000	
Replicate B	2,840,000	5,923,333	200,000	556,666	+	15	57,000	41,000
Replicate C	2,980,000	±5,219,716	150,000	±361,709	+	15	60,000	± 17,349
Grid 2								
Cercocarpus								
Replicate A	9,840,000		160,000		+	58	113,000	
Replicate B	2,260,000	14,366,666	390,000	283,000	+	30	92,000	135,000
Replicate C	31,000,000	±4,155,109	300,000	±115,902	+	70	200,000	±57,265
Open								
Replicate A	5,490,000		580,000		+	10	28,000	
Replicate B	780,000	4,956,666	80,000	320,000	+	2.5	118,000	53,000
Replicate C	8,600,000	±3,937,186	300,000	±250,599	+	70	14,000	±56,439

Table 3-2-19 THE ABUNDANCE OF SOIL MICROORGANISMS ON GRIDS 1 AND 2, JULY 1976

Sample	Total Bacteria Colonies/Gram	X̄ ± S.D.	Actinomycetes Colonies/Gram	X̄ ± S.D.	% Total Showing Denitrification	Nitrifiers Present	Fungi Colonies/ Gram	X̄ ± S.D.
Grid 1								
Cercocarpus								
Replicate A	10,000,000		320,000		43	+	3,000	
Replicate B	5,300,000	6,300,000	190,000	240,000	25	+	19,000	8,333
Replicate C	3,600,000	±3,315,117	210,000	±70,000	50	+	3,000	±9,238
Open								
Replicate A	2,700,000		190,000		25	+	9,000	
Replicate B	4,500,000	4,466,666	400,000	353,333	33	+	1,000	5,333
Replicate C	6,200,000	±1,750,238	470,000	±145,717	15	+	6,000	±4,041
Grid 2								
Cercocarpus								
Replicate A	3,200,000		270,000		15	+	26,000	
Replicate B	6,700,000	5,300,000	280,000	333,333	53	+	65,000	47,666
Replicate C	6,000,000	±1,852,026	450,000	±101,160	58	+	52,000	±19,858
Open								
Replicate A	6,800,000		220,000		53	+	37,000	
Replicate B	6,000,000	4,766,666	280,000	260,000	50	+	37,000	37,000
Replicate C	1,500,000	±2,857,154	280,000	±34,641	11	+	37,000	±0

species compared to open ground. Soil fungi respond to abundant organic matter and in particular to soil aeration with their numbers and activities diminishing as air movement is retarded (Buckman and Brady 1969).

The number of soil fungi also varied between the 1975 and 1976 samples (Tables 3-2-18 and 3-2-19). It is not unusual for large scale fluctuations to occur in the number of soil fungi (Buckman and Brady 1969). Therefore long term monitoring will be necessary to establish the average numbers of fungi for specific soils before the initiation of activities related to shale oil development.

3.2.5.5.2 Soil Actinomycetes

Actinomycetes are important contributors to the dissolution of soil organic matter and the liberation of nutrients. Actinomycetes develop best in moist, well aerated soil, although they remain more active during droughts than either bacteria or fungi. They do not persist at a pH of 5.0 or below and optimum development occurs at pH values between 6.0 and 7.5 (Buckman and Brady 1969).

Actinomycetes are generally more abundant than fungi but less abundant than bacteria (Buckman and Brady 1969). The abundance of actinomycetes on Tract C-b followed this general pattern with the number per gram falling between values for fungi and bacteria. The number per gram, which ranged from 240,000-556,000 is well below the maximum recorded number ($1x10^8$ - $9x10^8$) reported from other soils (Buckman and Brady 1969). This low abundance of actinomycetes was probably the result of generally dry soils, lack of humus, and high pH, all of which are factors considered unfavorable for maximum development.

As reported for soil fungi, actinomycete abundance was generally higher in soil samples obtained from beneath shrubs than in samples taken from open ground. As discussed for the fungi, this probably results from more favorable soil moisture levels, greater abundance of humus, and less compaction of the soil beneath shrubs than occurs in the open ground.

Variation in the number per gram of soil between years (1975, 1976) was relatively low and was appreciably lower than that recorded for soil fungi.

3.2.5.5.3 Soil Bacteria

Soil bacteria are commonly classified under two categories, autotrophic and heterotrophic. Autotrophs, which are never numerically abundant, obtain their energy from the oxidation of mineral constituents, such as ammonium (nitrification) and sulfur (sulfur oxidation), and are very important in the sustenance of higher plants. Most soil bacteria, however, are heterotrophic and their energy is dervied directly from the breakdown of soil organic matter. General purpose decay bacteria, ammonifying bacteria, and denitrifying bacteria are all heterotrophic in nature. Bacteria as a group are important in the full range of organic transactions and are able to rapidly increase in number when favorable soil conditions occur.

The numbers of bacteria present in the soil vary between different soil types, from year to year, and season to season, depending on temperature, moisture, aeration, and abundance of organic material. The number of bacteria per gram of soil on the average ranges from $1x10^9$ - $3x10^9$ (Buckman and Brady 1969) compared to a range of $4.5x10^6$ - $14x10^6$ in Tract C-b soil samples. This lower abundance of bacteria was probably the result of low amounts of organic material, dry soils, and poor aeration; the same conditions which resulted in relatively low numbers of fungi and actinomycetes. The number of bacteria is normally much higher than either fungi or actinomycetes (Buckman and Brady 1969). This general pattern was observed for Tract C-b soil samples with total bacteria counts one-two orders of magnitude higher than soil fungi or actinomycetes.

Soil bacteria were most abundant in soil samples taken from beneath shrubs following the pattern observed for fungi and actinomycetes. Factors which have been discussed above, including increased amounts of humus, favorable soil moisture, and good aeration, were probably responsible for the abundance of bacteria in these locations.

Although the percentage of nitrifying bacteria is not reported, all samples did show the presence of this important group. Since this group is a major source of fixed nitrogen for absorption by higher plants, any long-term decline in abundance or disappearance of these bacteria over widespread areas should be monitored closely.

No substantial differences were noted in the abundance of bacteria, fungi, or actinomycetes between grids in 1975 or 1976.

3.3 Vegetation Studies

The vegetation studies on Tract C-b have been broken down into six primary components: floristic studies, phytosociological studies, productivity studies, decomposition and litter fall studies, herb phenology studies, and stem growth studies. In this report each of the component studies is addressed separately in terms of rationale, objectives, experimental design, methods, and results and discussion.

Most of the tabular data summaries for the component studies have been relegated to the Data Appendix (Appendix B.3) of this report and only a limited number of tables have been included in the body of the text. All species lists have been included in the Appendix. In order to make the text more readable, common names for plant species have been used in nearly all cases in the narrative sections. Appendix IV-B, Table B-3-1 represents an alphabetical listing by common name with the associated scientific name for all the species mentioned in the text. If more information about a species is desired, refer to the annotated floral listing presented in Appendix IV-B, Table B-3-2 to B-3-2e.

3.3.1 Rationale for Component Studies

3.3.1.1 Flora

As part of any baseline study it is necessary to prepare a listing of the plant species which occur within a study area. This list presents the most basic inventory of the vegetation components. Many of the species are not common enough to be encountered in sampling programs such that the only information concerning these species is contained in the floral lists. For this reason it is more useful to include annotations in the flora pertaining to abundance and habitat preference than it is to simply provide a list of species. The listing of species also provides a means of searching for endangered or threatened species.

3.3.1.2 Phytosociological Studies

The study of vegetation through the use of plant ecological sampling methods provides an objective means of determining structural features of plant communities. Estimates of plant cover, density, height, and frequency are all useful in evaluating individual species roles and identifying community dominants.

In conjunction with the study of communities it is also of value to prepare a vegetation map. A portrayal of the vegetation types provides a means for evaluating the extent and location of each of the plant communities. A vegetation map is also a useful planning tool relative to evaluating development alternatives.

The combination of a vegetation map and quantitative structural descriptions derived from a sampling program provides the nucleus of a vegetation study necessary to evaluate the vegetation resources of an area.

3.3.1.3 Productivity Studies

The need to study plant production arises from a desire to know the amount of new plant biomass produced during the growing season. Since heterotrophic members of the ecosystem are dependent on the plants as a source of food (either directly or indirectly) an estimate of the amount of production is very useful in understanding trophic interactions. All plant parts are eventually consumed, either by browsing ungulates, leaf-eating insects, decomposers which eventually return even woody structures to organic and inorganic constituents, or other plant-eating organisms. Production studies on Tract C-b have included estimates of net production by the major shrub species and also estimates of net above ground herbaceous production. Economic compromises have limited the degree to which clipped samples have been fractionated.

3.3.1.4 Decomposition and Litter Fall Studies

Decomposition studies were undertaken for two primary reasons. By studying the rate of decomposition of plant tissue samples it is possible to estimate the activity of soil microorganisms which, as a group, can be easily overlooked in baseline studies. Also, by studying decomposition it is possible to estimate turnover rates, i.e., how long it takes for plant parts, such as leaves, to decompose and release inorganic and organic components. These studies provide an estimate of one of the important rate processes on the Tract and also focus on a group of organisms which may potentially be impacted by the operation of a shale oil processing facility.

Studies of litter fall in the woodlands provide estimates of the rate at which plant parts (leaves, cones, etc.) are shed from the trees. Process studies on trees have not been feasible because of the difficulty of estimating production of large woody plants. The litter fall studies provide tree data other than structural observations. In the bottomland sagebrush, litter fall studies provide similar information. In these areas the litter fall studies can be used in conjunction with the decomposition data, since estimates of the rate of decomposition of sagebrush leaves are available for the bottomland sites.

3.3.1.5 Herb Phenology

The study of herb phenology was conducted in order to estimate dates for development of major herb species and also to estimate the percentage of individuals which flower and produce seed. Dates of phenological events are of greater importance in evaluating standing crop changes than are calendar dates.

3.3.1.6 Shrub Stem Growth Studies

Stem growth studies were undertaken in order to estimate the amount of newshoot elongation and also to evaluate individual shrub responses to the influence of browsing by mule deer. The study was originally designed to follow the phenological development of marked shrubs, but the entire program was reduced to measurement of marked shoots. The primary reason for the study was to determine the seasonal change, flowering time, and senescence of the major shrub species.

3.3.2 Objectives of Component Studies

3.3.2.1 Flora

The primary objective for the floristic study was to obtain as complete a listing of the vascular plants as possible which grow within the Tract C-b study area.

In conjunction with the listing of species, annotations were developed concerning abundance and habitat preference for each species.

3.3.2.2 Phytosociological Studies

All of the following studies were conducted in order to obtain the data necessary for preparation of descriptions of plant communities for Tract C-b.

3.3.2.3 Vegetation Mapping

The primary objective of the vegetation mapping study was to prepare a map of plant communities which occur within the study area. This map was to be prepared at a scale which would be useful for evaluating alternatives for proposed developments and also to be used as a basic map from which other maps may be derived, e.g., habitat types.

3.3.2.4 Broadly Based Vegetation Sampling Program

The primary objective of this program was to obtain community structural data (cover, density, and frequency) from representative stands of each of the plant community types.

Secondarily, this program was designed to provide the necessary data for evaluating the amount of heterogeneity within the major vegetation types.

3.3.2.5 Intensive Study Plot Studies

The primary objective of the intensive plot studies was to provide permanent locations for long-term collection of structural plant community data for representative stands of the major vegetation types.

Secondarily, these intensive study plots also provide locations for herb production estimates, herb phenology observation, shrub growth studies, decomposition studies, tree growth studies, and litter fall studies.

Thirdly, paired fenced and open plots were established in order to estimate the long-term effects of grazing removal.

3.3.2.6 Productivity Studies

The first objective of the productivity studies was to obtain an estimate, net above ground primary production for herbaceous species.

The second objective was to estimate yearly production for major shrub species. This estimate was to include biomass accumulated in newshoots, leaves, and radial growth.

3.3.2.7 Decomposition and Litter Fall Studies

The objective of the decomposition studies was to obtain an estimate of the rate of decomposition of leaves from selected shrub species and a cellulose standard in each of the major vegetation types. These data were then to be used in assessing turnover rates for organic and inorganic nutrients.

The objective of the litter fall studies was to estimate the seasonal rate of canopy litter production in two pinyon-juniper woodland sites and in the bottomland sagebrush site.

3.3.2.8 Herb Phenology

The first objective of the herb phenology study was to provide a general estimate of the phenological development of the major herb species.

Secondly, this study was to provide an estimate of the percentage of individuals in the populations which flower and produce seed.

Thirdly, the study was designed as a feasibility study to determine whether herb phenology was a suitable parameter for long-term monitoring of the vegetation.

3.3.2.9 Shrub Stem Growth Studies

The first objective of this study was to provide an estimate of stem growth rates for major shrub species at the intensive study sites.

Secondly, this study was to provide an estimate of the effect of deer browsing by comparing growth patterns inside and outside of the fenced plots.

(The original objective of estimating the phenological development of the major shrub species was eliminated because of economic considerations.)

3.3.3 Experimental Design

3.3.3.1 Phytosociological Studies

3.3.3.1.1 Broadly Based Sampling Program

This sampling program was designed such that structural data could be obtained for the 15 vegetation types within the study area. A greater level of sampling intensity was devoted to the major, more widespread vegetation types (pinyon-juniper woodlands, chained rangelands, upland sagebrush, and bottomland sagebrush communities). These four types cover most of the Tract itself and also account for the greatest area of the entire study area. Other vegetation types are much more limited in distribution on the Tract or occur only within the one-mile buffer zone surrounding the Tract. For these reasons only one stand was sampled for douglas-fir forests, mixed mountain shrub communities, greasewood communities, rabbitbrush communities, and bunchgrass communities. Disturbed sites were sampled at a greater intensity in order to better assess early successional developments following disturbance. Since only herbaceous data were collected at these sites it was posssible to sample the sites rather quickly. Vegetation types which were very limited in extent were not sampled, but rather descriptions were based on observations of apparent dominant species (Table 3-3-1).

Table 3-3-1 VEGETATION SAMPLING SUMMARY AND PHYTOSOCIOLOGICAL STUDIES EXCLUSIVE OF INTENSIVE STUDY PLOTS

	No. of Sampled Stands	No. of Quarter Method Tree Points/Stand	No. of Shrub Transects per Stand	No. of Herb Quadrats 1.0m^2 per Stand
Pinyon-Juniper Woodland	3	40	20	20
Douglas-fir Forest	1	--	10	10
Mixed Mountain Shrub	1	--	20	20
Chained Rangeland	3	--	20	20
Upland Sagebrush	3	--	20	20
Bottomland Sagebrush	2	--	20	20
Greasewood	1	--	20	20
Rabbitbrush	1	--	20	20
Bunchgrass	1	--	20	20
Disturbed Sites (Annual Weed)	7	--	--	10
Marshes[1]	No Sampling Data			
Great Basin Wild Rye[1]	No Sampling Data			
Riparian Community[1]	No Sampling Data			
Agricultural Areas[1]	No Sampling Data			
Ponds[1]	No Sampling Data			

[1] These vegetation types are very limited in extent within the study area. Descriptions of these communities are based on observations only.

All sampled stands were selected on the basis of apparent homogeneity, i.e., stands were located within a single vegetation type so that areas of overlapping types were not sampled. Since edge effects can be important, areas at least 4 hectares (10 acres) in size were selected for sampling. Because of the nature of some of the vegetation types some of the sampled stands were smaller in area, especially the disturbed sites. For the vegetation types of limited distribution the stand selection was extremely important since only one site would be sampled. Stand selection was made after reconnaissance of the entire area had been completed. The stands which were selected were those which were judged to be representative of that particular type. No attempt was made to estimate variability within these types of limited extent.

Selection of sampling stands for the major vegetation types was governed primarily on the basis of size and homogeneity. The purpose of sampling more than one area was to describe the amount of variation within these types.

Communities were sampled according to the schedule outlined in Table 3-3-1. Individual stands were sampled in a stratified random manner. The first quadrat was placed according to random coordinates; the remaining quadrats and shrub transects were placed at fixed intervals from the first.

3.3.3.1.2 Intensive Study Plots

The intensive study plots (Sites 1-6 in Figure 3-3-1) were designed and implemented in order to provide long-term study locations on Tract C-b. At the outset of the project it was decided that the small intensive sites could be used to augment the broadly based sampling program and in this way make possible the use of permanently located quadrats and transects which could be re-sampled throughout the life of the project. Since considerable cost and effort was required for installation of the plots, it was decided to construct them only in the major vegetation types. Plots were located at two sites in the pinyon-juniper woodlands and at two sites in the chained rangelands. Single plots were placed in the upland and bottomland sagebrush communities. Selection of these study locations was based on several factors. The sites had to be contained wholly within a vegetation type, and each site had to be large enough to accommodate two 50-meter by 70-meter plots with a sufficient buffer zone surrounding them in order to reduce edge effects. Additionally, the plots had to be located on sites which would not be disturbed throughout the life of the project, i.e., not on sites to be occupied by processing facilities, stockpiles, disposal areas, reservoirs, parking areas, etc. In order to evaluate potential influences of shale oil development on the pinyon-juniper woodlands and chained rangelands, one of the plot locations for each of these types was located in what was expected to be a site downwind from the proposed processing facility

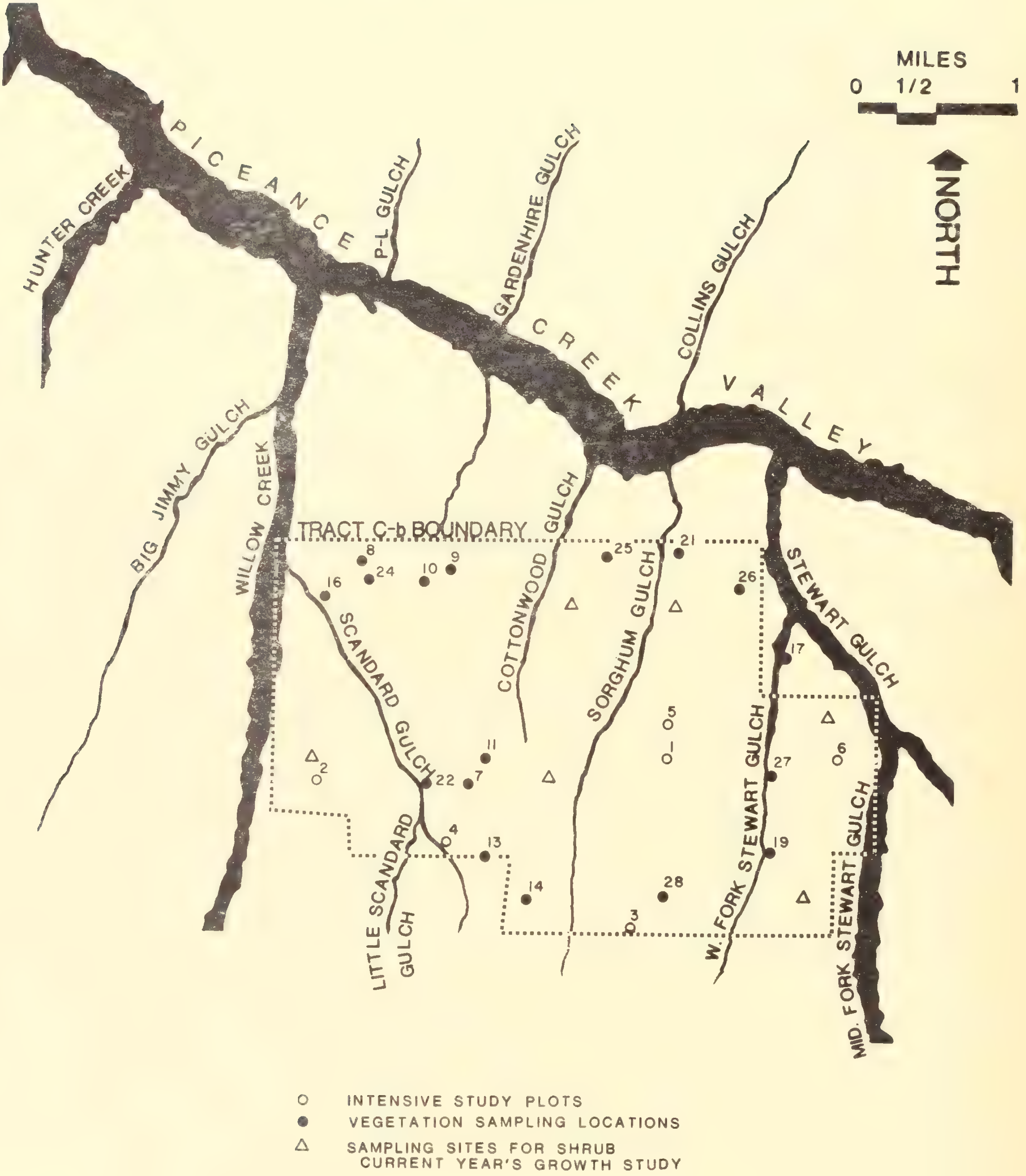


FIGURE 3-3-1 VEGETATION SAMPLING SITES

and shale disposal area. The other study sites for these types were located in remote portions of the Tract in areas where no development would occur, and the vegetation would not be influenced by processing activities. The same design was originally planned for the sagebrush communities, but only one site which met the stated criteria for each sagebrush site was located within the Tract boundaries. Because the sagebrush types are not as abundant as the woodlands and chained rangelands, it was decided that single sites would suffice for long-term study of these types. When all the restrictions for plot locations were implemented, it was surprising how few areas were available for study within the Tract boundaries.

The plots at each study site were established as pairs with one plot enclosed with a 2.5 meter deer fence. The plots were 50-meters by 70-meters, and were placed 10 meters apart. At one end of each plot a grid of 25 permanent 1.0 m^2 circular quadrats was placed. Quadrats were placed in 5 rows 10 meters apart each with 5 quadrats positioned at 10-meter intervals. The 10 meter center-line distance between two quadrats was used as a line intercept to estimate shrub cover. Twenty intervals per plot were sampled. In order to estimate shrub density an area defined by the 10-meter interval between quadrats and a distance of two meters on either side of the centerline was sampled. In the woodland plots all of the trees which occur within the 1600 m^2 defined by the quadrats at the corners of the grid were tagged and measured (diameter breast height and height). The area at the opposite end of the plot was used for other botanical studies.

One of the plots was fenced at each site in order to evaluate the effect of grazing removal for a long time period on the Tract. We recognize that the presence of a fence can alter local microclimatic differences; however, during the baseline period the only apparent changes resulting from the fences seems to be limited to those areas within 3-5 meters of the fence, which are not sampled. Other fence influences such as reducing wind velocities and shadow effects are not apparent in the areas away from the fences.

Removal of grazing has produced some changes including an apparent build up of the mulch layer and also a slight increase in the overall size of individual shrubs.

3.3.3.2 Productivity Studies

3.3.3.2.1 Herb Production Studies

The herb production study was designed to provide an estimate of above ground net primary production. Quadrat clipping was conducted at monthly intervals throughout the growing season at each of the intensive study plots. The portion of the plot at the opposite end of the permanent quadrat grid was used for obtaining the clipped samples. In addition to clipping in the paired open and fenced plots, a third sampling location was also established. This plot consisted of a 50-meter by 50-meter barbed wire enclosure which is seasonally fenced and opened. Initial fencing of these plots (one at each intensive study site) was accomplished in April 1975; the fences were removed in November 1975 and then replaced in April 1976. Studies in these plots were initiated at the request of the wildlife researchers in an attempt to separate the amount of area usage by deer and domestic livestock. During the first year of study, clip samples were obtained from mid-May to mid-August (at monthly intervals). Each plot at each intensive study site was sampled by clipping ten 0.1 m^2 randomly located circular quadrats, for a total of thirty plots per site per date. Following analysis of these data the program was altered for the second year of sampling. Sampling dates were changed to mid-April through mid-August (exclusive of June for plots 1-3, 5, and 6; and exclusive of July for plot 4). Quadrat size was changed to 0.25 m^2 for plots 1, 2, 5, and 6, and sample size was increased to 15 quadrats per plot per site for all locations. Clipped samples were fractionated into current live (all green herbage together) standing and attached dead, and litter and prostrate dead for all samples both years. No separation of the current live fraction was made. All clipping studies were conducted at the intensive study sites; no estimate of production was made for other vegetation types.

3.3.3.2.2 Shrub Production Studies

Shrub production was also estimated using a harvest method; however, the studies were based on estimates of biomass increases in individual plants rather than on changes in biomass of a fixed ground area. Total production estimates were made on the basis of density values obtained from the phytosociological sampling program. Only the more common shrub species were studied. The primary goal of this study was to provide a general estimate of shrub production such that it would be possible to compare Tract C-b with other major vegetation types. The sampling intensity for this program was greater during the first year of the baseline studies (Table 3-3-2). The increases in the herb production study were offset by a decrease in intensity in the shrub production studies during the second baseline year.

3.3.3.2.3 Current Year's Growth for Antelope Bitterbrush and Mountain Mahogany

During the second year of the baseline program a second level of shrub production was initiated in order to estimate the current year's shoot production for mountain mahogany and antelope bitterbrush, two of the most important mule deer browse species on the Tract. Since the other shrub production studies were not designed to estimate this parameter a separate study was conducted. At six locations on the Tract (Figure 3-3-1), three located in pinyon-juniper woodlands and three in the chained rangelands, a sample of

Table 3-3-2 1975 SAMPLE NUMBERS AND LOCATIONS FOR SHRUB PRODUCTIVITY STUDY

	No. of sampled stems	Clipping location
Artemisia tridentata	120	1-F, 1-0, 2-F, 2-0 3-F, 3-0, 4-F, 4-0
Purshia tridentata	60	1-F, 1-0, 2-F, 2-0
Cercocarpus montanus	45	1-F, 1-0, 2-0
Amelanchier alnifolia	45	1-F, 1-0, 2-0
Ceratoides lanata	20	Scandard Gulch
Chrysothamnus nauseosus	20	Ridge east of Cottonwood Gulch and ridge east of Sorghum Gulch
Juniperus osteosperma (sapling)	20	"
Pinus edulis (sapling)	20	"
Total	350	

the current year's growth (new shoots with attached leaves) was clipped from randomly selected shrubs. At each location five shrubs were sampled with a total of 10 new shoots being clipped from the ends of a randomly selected stem. The total number of shoots on that stem and the total number of stems per plant were recorded. This provided a total of 50 clipped new shoots for mountain mahogany and antelope bitterbrush at each sampling location; a total of 150 for all chained areas combined and 150 for pinyon juniper areas. Shoots were returned to the laboratory, measured for length; the leaves were separated from the shoots; both fractions were then dried and weighted. Production estimates were then calculated on the basis of: mean weight per shoot times mean number of shoots per stem times the mean number of stems per plants times the number of plants per hectare. Total design of this study was to allow for comparison between chained rangelands and pinyon-juniper woodlands.

3.3.3.3 Decomposition and Litter Studies

3.3.3.3.1 Decomposition Studies

The decomposition studies were designed to evaluate rates of decomposition in the major vegetation types. Leaves of three shrub species (mountain mahogany, serviceberry, and big sagebrush) and a cellulose standard (Watman #50 filter paper) were used as decomposition test materials. A total of 640 decomposition packets were set out in the intensive study plots in November 1974 following the numerical placement shown in Table 3-3-3. Enough samples were set out so that retrievals could be made more than once. The original design called for collections to be made only twice, with half of the samples being collected each time. This was later modified so that three collections could be made. Since differences in decomposition were not expected in the fenced and open plots, samples were treated as combined estimates. Samples were retrieved in April 1976 and again in September 1976. Enough samples remain for a final collection in spring 1977.

3.3.3.3.2 Litter Fall Studies

The litter fall studies were designed to provide an estimate of the rate of fall of vegetation canopy components (leaves, stems, fruits, and flowers) in the major vegetation types. Estimates were made by placing 10 0.25 m^2 litter traps in each intensive study plot (10 each in open and fenced plots). The original design called for placement of traps at all intensive study plots, however, this was subsequently changed and the traps in the chained rangeland and upland sagebrush plots were removed. The approach was ineffectual in collecting litter in these sites mostly because of the low stature of the vegetation and problems associated with surface air turbulence. Samples were collected twice a year, once in the spring and once in autumn, in order to assess major seasonal differences.

Table 3-3-3 DECOMPOSITION SAMPLE LOCATION PATTERN

Samples	Sampling Locations[1]											
	1-0	1-F	2-0	2-F	3-0	3-F	4-0	4-F	5-0	5-F	6-0	6-F
Cercocarpus montanus (leaves)	X	X	X	X					X	X	X	X
Amelanchier (leaves)	X	X	X	X					X	X	X	X
Artemisia tridentata (leaves)					X	X	X	X				
Cellulose Standard (Watman #50 filter paper)	X	X	X	X	X	X	X	X	X	X	X	X

---

[1] Each "X" represents placement of ten packets on the surface and ten packets at a depth of 10 cm. Plots 1 and 2 - chained rangeland, Plot 3 - upland sagebrush, Plot 4 - bottomland sagebrush, Plots 5 and 6 - pinyon-juniper woodland; 0 = open, F = fenced

3.3.3.4 Herb Phenology

Herb phenology data were collected at the six intensive study plots. Ten of the twenty-five permanently marked quadrats were used (even numbered quadrats 1-20) as sampling sites; however, the quadrat size was 0.1 m^2 at sites 3 and 4, and 0.25 m^2 at sites 1, 2, 5, and 6.

Phenological observations were made at monthly intervals from mid-May to mid-August. Observations were limited to the most common herb species at each site (Table 3-3-4). Where possible observations were made on species which occurred at most sites; however, this was feasible for only two species (*Oryzopsis hymenoides* and *Agropyron smithii*).

3.3.3.5 Shrub Stem Growth Studies

Stem growth studies were accomplished by marking and repeated measurement of twigs of shrubs located in the intensive study sites. At plots 1 and 2 (chained rangelands) and at plot 5 (pinyon-juniper woodland), observations were made on mountain mahogany and serviceberry. Observations were made on big sagebrush at plot 3 (upland sagebrush) and plot 4 (bottomland sagebrush). At plot 6 (pinyon-juniper woodland) observations were made on serviceberry. Five shrubs were selected in both the open and fenced plots. Four twigs were selected and marked on each shrub for a total of 20 marked twigs per plot. (The total number of marked twigs has decreased since the initial observations were made because of the loss of the tags. Deer browsing, rabbit browsing, and mechanical damage have all contributed to tag loss). Marked twigs have been measured twice each year in the spring and in the autumn.

3.3.4 Brief Methodological Descriptions

A more detailed description of methods is presented in Appendix IV-A, Section 3.

3.3.4.1 Flora

The preparation of the list of species was accomplished by recording all species observed during any of the sampling activities on the Tract. The sampling program necessitated that each of the vegetation types be examined in some detail such that most of the available habitats were visited and component species were recorded. Other areas, such as sheltered box canyons and rock escarpments which were not sampled, were visited specifically to note the species growing there, since these sites were the most likely to harbor any threatened or endangered vascular species.

Table 3-3-4 SPECIES USED IN HERB PHENOLOGY STUDY

Site Number	Species Studied
1 (Chained rangeland)	Oryzopsis hymenoides Agropyron desertorum
2 (Chained rangeland)	Agropyron desertorum Sitanion longifolium Oryzopsis hymenoides
3 (Upland sagebrush)	Agropyron smithii Phlox longifolia Sphaeralcea coccinea
4 (Bottomland sagebrush)	Bromus tectorum
5 (Pinyon-juniper woodland)	Oryzopsis hymenoides Oryzopsis micrantha
6 (Pinyon-juniper woodland)	Phlox longifolia Festuca brachyphylla (?) Agropyron smithii

3.3.4.2 Phytosociological Studies

3.3.4.2.1 Vegetation Mapping

The vegetation map was prepared using a modification of Küchler's (1967) comprehensive method which entails the combined use of air photo interpretation and field checking.

3.3.4.2.2 Broadly Based Vegetation Sampling Program

The sampling of vegetation stands as part of this program (Table 3-3-5) was conducted using the point quarter method (Cottam and Curtis 1956) to estimate tree densities, frequencies, and basal area; Lindsey's (1955) line strip method to estimate shrub cover, density, and frequency; and a quadrat method for estimating herb frequency and ground layer parameters.

3.3.4.2.3 Intensive Study Plot Studies

The sampling at the intensive study sites was accomplished in the same manner for shrubs and herbs except that herb quadrats and shrub transects are permanently located. Trees were sampled by making actual counts within the sampling grid outlined by the permanent quadrat positions.

3.3.4.3 Productivity Studies

3.3.4.3.1 Herb Production Studies

Net aboveground herb production has been estimated using a harvest method (Milner and Hughes 1968). The basic approach has been to use small clip quadrats randomly located at the intensive study sites.

3.3.4.3.2 Shrub Production Studies

Shrub production has also been studied using a harvest method (Newbould 1967). Estimates have been made by clipping entire stems at ground level and then extrapolating to weight of entire plants based on the mean number of stems per plants. Standing crop values were then converted to areal estimates based on density estimates. Production was estimated by comparing standing crop values in April and September. Production estimates from this study include growth of new shoots, leaves, and radial increases in woody tissue.

In order to provide an estimate of new shoot production (i.e., that portion of a shrub available for deer consumption) a second

Table 3-3-5 STAND NUMBERS AND VEGETATION TYPES FOR AREAS SAMPLED AS PART OF THE BROADLY BASED SAMPLING PROGRAM

Stand Number[1]	Vegetation Type
7	Chained Pinyon-Juniper Rangeland
8	Upland Sagebrush Community
9	Pinyon-Juniper Woodland (East-facing Slope)
10	Chained Pinyon-Juniper Rangeland
11	Upland Sagebrush Community
12	Pinyon-Juniper Woodland
13	Pinyon-Juniper Woodland
14	Chained Pinyon-Juniper Rangeland
15	Upland Sagebrush Community
16	Bottomland Sagebrush Community
17	Rabbitbrush Community
18	Greasewood Community
19	Bottomland Sagebrush Community
20	Bunchgrass Community
21	Douglas-fir Forest
22	Annual Weed Community
23	Annual Weed Community
24	Annual Weed Community
25	Annual Weed Community
26	Annual Weed Community
27	Annual Weed Community
28	Annual Weed Community
29	Mixed Mountain Shrubland

[1] See Figure 3-3-1 for stand locations

study was also conducted. New shoots (current year's growth) were clipped from a sample of shrubs. The number of new shoots per stem, and the number of stems per plant were counted so that extrapolations to weight per area estimates could be made. Shoots were clipped in September. In the lab leaves were separated from stems and weighed separately.

3.3.4.4 Decomposition and Litter Fall Studies

Decomposition was studied using leaf samples of known weight enclosed in nylon mesh bags. Bags were placed in the field, retrieved after a period of time, and were reweighed. Percent weight loss was then used as a measure of decomposition. Samples were placed on the surface and at a depth of 10 cm.

Litter fall in the woodlands and bottomland sagebrush community was studied using randomly located 0.25 m^2 litter traps (Newbould 1967).

3.3.4.5 Herb Phenology

Herb phenology was studied by repeated sampling of permanently marked quadrats. The number of individuals in each quadrat was counted and separated into eight growth stages (phenophase): vegetative stage, production of culms, flower and inflorescence buds, blossoming, unripe seeds and fruits, ripe seeds and dispersal, yellowing of leaves, death or partial dieback.

3.3.4.6 Shrub Stem Growth Studies

The study of shrub stem growth has been conducted by repeated measurement of marked twigs on the major shrub species. Individual plants located inside and outside of the fences at the intensive study plots were studied to evaluate the effect of deer browsing on stem development.

3.3.5 Results and Discussion

3.3.5.1 Flora

The flora of Tract C-b is composed of 230 species of vascular plants which represent 163 genera and 54 families. As in most areas of west-central United States, the sunflower family (Compositae) had the largest number of species (51) followed by the grass family (Gramineae) with 29 species. These two families account for 35 percent of the flora. Only two other families, the mustards (Cruciferae) and the legumes (Leguminosae), were represented by more than 10 species (13 species each). Twenty-nine families were represented by a single species.

Tract C-b lies in a floristic transitional zone between the Rocky Mountains to the east and the Intermountain West-Great Basin region farther west. The species which occur on the Tract reflect the influences of these two floristic regions. Some of the species which grow on dry, exposed sites are characteristic of the Intermountain Region, whereas sheltered draws and north-facing slopes harbor species more typical of mountainous regions.

While the Tract is characterized by pinyon-juniper woodlands and open shrublands, 68 percent of the flora is composed of herbaceous perennial plants. Of these species only a small percentage are widespread on the Tract; many of the species occur sporadically and are known from only a few locations. Native and introduced annuals account for 16.5 percent of the species. The introduced species (mostly European and Asian weeds) are common dominants on disturbed sites and roadsides. The native annuals occur mostly in undisturbed natural vegetation types.

None of the species identified from the Tract are considered to be threatened or endangered at either a state or national level. Based on observations from areas adjacent to the Tract and from other areas in the Piceance Basin, the flora of the Tract appears to be typical of this region of western Colorado.

A complete annotated listing of the species which occur on the Tract is presented in Appendix IV-B, Tables B-3-2 to B-3-2e.

3.3.5.2 Description of Plant Communities

Included in this section are descriptions of the vegetation types which occur on Tract C-b. These communities are characteristic of this part of western Colorado. The variety of vegetation types is as great as it is owing primarily to the presence of the Piceance Creek valley within the study area. None of the described vegetation types are unique to the study area.

Supporting sampling data for these descriptions have been relegated to the data Appendix. Readers should refer to the Vegetation Map for Tract C-b (Pocket Figure 3-3-2, refer to pocket, inside back cover) in order to place the vegetation types in proper physiographic perspective. The information on environment presented in the following descriptions has been taken from the microenvironment section of this report.

Following the descriptions of the communities is a section which examines the similarities among the vegetation types. Shrub importance value (the sum of relative cover, relative density, and relative frequency) has served as the parameter for comparison of the vegetation types.

3.3.5.2.1 Pinyon-Juniper Woodlands

3.3.5.2.1.1 General Location and Distribution

Pinyon-juniper woodlands constitute the most common and widespread vegetation type in this part of western Colorado. Total environmental characteristics favor the development of this type, but local soil, temperature, topographic and moisture conditions cause the mosaic of plant communities which occur in the region.

On the Tract this vegetation type occurs primarily on ridges and dry slopes and is mostly absent from alluvial deposits, talus slopes, and loamy soils of uplands. At one time these woodlands covered most of the Tract; however, Bureau of Land Management (BLM) chaining operations in 1966 removed approximately 2500 wooded acres within the Tract boundaries. Even though the total extent of the pinyon-juniper woodlands was reduced by more than 50 percent, it remains as one of the most common vegetation types on the Tract.

3.3.5.2.1.2 Structure and Composition

The tree layer of these woodlands is composed of varying amounts of pinyon pine, Utah juniper, and Rocky Mountain juniper. Composition percentages vary from nearly pure stands of pinyon pine on broad ridges to steeply-sloping sites where Utah juniper is the dominant species. All stands of this vegetation type, regardless of dominant species, tend to have limited canopy cover (32 percent) and low density (approximately 210 trees per hectare, Apendix IV-B, Table B-3-3). The open canopy and wide spacing of individuals alter incoming solar radiation which seems to have a limited effect on understory development; however, competition for water and nutrients tends to restrict the growth of shrubby and herbaceous plants.

Most woodlands on the Tract have poorly developed herb and shrub layers. Shrub-layer dominants vary from site to site. Big sagebrush usually occurs as the dominant species on ridgetop stands. Species more characteristic of mixed mountain shrublands (serviceberry, bitterbrush, and mountain mahogany) tend to dominate stands located on hillsides. In the open understory stands, shrub cover averages 4 percent, and total shrub density averages approximately 3200 shrubs per hectare (Appendix IV-B, Tables B-3-4, B-3-5). Herb cover in these same stands averages 15 percent with western wheatgrass, fleabane, sheep fescue, Junegrass, needle-and-thread grass, and Indian ricegrass occurring as the dominant species. (Appendix IV-B, Tables B-3-6 and B-3-7; Stands 9 and 12).

Pinyon-juniper woodlands also occur to a limited extent on north-facing slopes. In these stands the understory is much more dense and has the appearance of a mixed shrub community except for the presence of the trees. Shrub cover and density are much greater (24 percent and 26,000 individuals per hectare, respectively). The dominant shrub species in these stands is snowberry (Appendix IV-B, Table B-3-8). The herb layer is much better developed in these stands and herb cover averages 26 percent. Common understory species are fairy candelabra, Junegrass, western wheatgrass, and needle-and-thread grass (Appendix IV-B, Tables B-3-6 and B-3-7). Pasque flower and sugar bowls, rare species on the Tract, occur in these pinyon-juniper stands.

Considerable variability exists among pinyon-juniper woodlands. Average shrub layer similarity among all sampled pinyon-juniper stands is 47 percent (Table 3-3-6). Similarity is calculated on the basis of the formula $C = [2w/(a+b)] \times 100$, where C = similarity index, w = sum of importance value shared by each species in compared stands, a = sum of importance value in Stand A, and b = sum of importance value in Stand B. Average similarity is computed by determining the arithmetic mean of similarity indices between all possible stand combinations.

The average similarity includes comparison of open understory with dense understory stands. The only stand on the Tract with a dense understory is Stand 13. Recalculation of average similarity excluding data from this stand results in an average similarity of 54 percent. This suggests greater homogeneity among the open understory pinyon-juniper woodlands.

3.3.5.2.1.3 Stability, Diversity, and Succession

The pinyon-juniper woodlands are one of the most stable plant communities in the region. Dendrochronological data show that the oldest trees are more than 200 years old and the largest trees are more than 76 cm (2.5 feet) in diameter; however, most of the trees are less than 10 meters (30 feet) tall. The pinyons and junipers do not appear to be invading other vegetation types. Saplings occur in the upland sagebrush communities, but establishment of individuals appears to occur intermittently. Herb species density averages less than 10 species per quadrat which is an intermediate value compared with other plant communities.

3.3.5.2.1.4 Environment

The pinyon-juniper woodlands are developed mostly on Redcreek and Rentsac channery soils. These soils tend to be thin and are developed over fractured or non-fractured sandstone bedrock. While these soils have adequate levels of nitrogen, they tend to have low or deficient potassium and phosphorus concentrations. (Based on data from soils report).

Table 3-3-6 MATRIX OF SIMILARITY VALUES[1] FOR SAMPLED PINYON-JUNIPER WOODLAND STANDS

PLOT/STAND NUMBERS	5-F	5-0	6-F	6-0	9	12	13
5-F	-						
5-0	62.2	-					
6-F	45.8	40.5	-				
6-0	59.6	53.1	69.2	-			
9	46.0	44.7	38.3	43.2	-		
12	56.8	53.6	60.4	78.6	48.6	-	
13	34.5	50.7	14.9	29.4	27.3	33.3	-

PLOT/STAND NUMBERS

[1] Similarity values are in percents

Precipitation values for the Tract are highly variable. Most of the precipitation falling in the woodlands either moistens the surface soil layers, evaporates, or sublimates in the case of snow. Runoff is minimal, and likely occurs only during extreme, intense thunderstorms.

Temperature profiles constructed for the four major vegetation types show that pinyon-juniper woodlands are the coldest sites. This relationship is true of the entire temperature profile. Effective solar radiation is decreased by canopy cover. This effect is augmented in winter by snow pack.

Fires occasionally occur in the pinyon-juniper woodlands. Several burned sites can be found from one fire in the northeast portion of the area between lower Stewart Gulch and Piceance Creek (Pocket Figure 3-3-2). This fire caused complete destruction of the woodland. Several charred trees remain standing but most have fallen. Few saplings occur in the area, and the most abundant species is Indian ricegrass. Fires are probably not common since the open canopy and sparse understory do not provide the fuel necessary for frequent fires.

3.3.5.2.1.5 Current Land Use and Management

The pinyon-juniper woodlands are used as livestock grazing areas during late spring, summer and early fall. In mid-summer most of the cattle have moved to higher elevations and are not found on the Tract. Maximum grazing use occurs in May and October when the livestock are being moved from lower-valley winter range to and from native upland ranges.

Large areas of the Tract woodlands have been chained as part of a range improvement program. By removing the trees, production in herb and shrub layers has been stimulated thus increasing available forage. After the trees were removed, range grasses were seeded in order to increase grass production.

3.3.5.2.2 Chained Pinyon-Juniper Rangeland

3.3.5.2.2.1 General Location and Distribution

The chained rangelands constitute a highly variable and somewhat artificial plant community. This vegetation type has been produced through management practices of the BLM and its distribution is determined by BLM selection of chaining sites. Chaining is mostly restricted to ridges and gentle hillsides where it is possible to operate bulldozers necessary for the chaining operation. On the Tract the chained rangelands occur primarily in the central portion of the study area and cover approximately 45 percent of the Tract.

3.3.5.2.2.2 Structure and Composition

The general appearance of the chained rangelands is that of a shrubland with many fallen trees. Total shrub density is approximately 4750 individuals per hectare and shrub cover averages 11 percent. The dominant species include big sagebrush, bitterbrush, and saplings of pinyon pine and Utah juniper. In some locations snowberry occurs as a dominant species, but it tends to be locally abundant rather than occurring as a widespread dominant. (Appendix IV-B, Tables B-3-9, B-3-10, and B-3-11).

Since chaining in 1966, the pines and junipers have made some recovery. Average sapling densities for these two species were 324 pines per hectare and 260 junipers per hectare.

Cover by herbs in the chained rangelands averages 32 percent which is approximately twice the value in pinyon-juniper woodlands. Three perennial grass species are common: Indian ricegrass, squirreltail grass, and western wheatgrass. Many annual species also occur including cheatgrass, goosefoot, stickseed, and tansy mustard, but cheatgrass is the most common (Appendix IV-B, Tables B-3-6 and B-3-7; Stands 7, 10 and 11).

3.3.5.2.2.3 Stability, Diversity, and Succession

The chained rangelands constitute ecologically unstable communities. Destruction of the woodlands has greatly altered the original vegetation and has initiated successional changes which will continue until the woodlands become re-established. The observed variation within the chained rangeland areas results from original differences in the woodlands and also from differential successional rates. Where environmental factors are more favorable, successional rates will likely be greater. The heterogeneity is reflected in the average similarity (53.8 percent) among all sampled, chained rangeland stands (Table 3-3-7). The fact that this value is somewhat higher than the average value for pinyon-juniper woodland most likely reflects the lack of chained sites on relatively steep, north-facing slopes. The intensive study sites (Plots 1 and 2) are 55 percent similar to the other sampled chained sites.

Successional changes within these communities will take place slowly. It may take as long as 200 years for these sites to return to a woodland vegetation.

Table 3-3-7 MATRIX OF SIMILARITY VALUES[1] FOR SAMPLED CHAINED RANGELAND STANDS

PLOT/STAND NUMBERS	1-F	1-0	2-F	2-0	7	10	14
1-F	-						
1-0	87.6	-					
2-F	61.2	62.0	-				
2-0	49.3	48.6	72.0	-			
7	50.7	52.8	44.2	42.9	-		
10	75.6	85.7	58.3	43.7	51.0	-	
14	32.1	36.2	40.1	42.2	64.7	30.6	-

PLOT/STAND NUMBERS

[1] Similarity values are in percents

3.3.5.2.2.4 Environment

Soils in the chained rangelands have essentially the same characteristics as in the pinyon-juniper woodlands. However, other environmental factors have been altered as a result of chaining. Solar radiation is much more uniform in the chained areas because of the absence of a tree canopy. Radiation intensities are reduced under the fallen timber; however, these conditions are different from those produced by a vegetation canopy.

Chained sites are the warmest sites of the four vegetation types on Tract C-b during cool weather. Differences in temperature between extremes in depth and height are the greatest of all sites. The behavior of the temperature profile is markedly similar to that of the woodland sites. The extreme difference in actual mean temperature between the chained areas and the woodland sites is due to the absence of canopy cover in the former type.

Snow distributional patterns have been altered as a result of chaining. Snow tends to collect in the lee side of the windrows of fallen trees, thus producing an effect on the distribution of soil moisture.

Fires could occur within the chained areas and the fallen timber would supply an abundance of fuel. To date, however, no evidence of fire has been observed in these areas.

3.3.5.2.2.5 Current Land Use and Management

Currently the chained rangelands are used for cattle grazing. Since chaining, no further management practices have been employed in this vegetation type.

Additionally, these sites are used as firewood cutting areas under permits issued by the BLM. Woodcutters selectively remove trunks and larger branches, but leave behind tree bases, roots, and smaller branches.

3.3.5.2.3 Big Sagebrush Communities

Big sagebrush communities are widely distributed throughout the Piceance Basin and occur as two structurally different types. On valley floors and on alluvial fans big sagebrush occurs at very high densities and attains heights in excess of three meters. It also occurs in nearly pure stands on ridges and as a dominant species in clearings in the pinyon-juniper woodlands. On these sites the sagebrush is much smaller in stature and does not reach densities as great as those attained in the valley communities. The ridgetop communities extend to elevations as great as 8,500 feet. Variation in the size and density of sage plants in the valleys results from a number of environmental parameters as well as possible genetic sub-specific differences. The upland sagebrush sites occur primarily on Forelle and Piceance loam soils which are generally characterized by low or deficient phosphorus and potassium concentrations. The bottomland sagebrush stands, however, occur on Glendive and Rivra loam soils which are characterized by normal, high, or excessive amounts of these same nutrients. Differences in sagebrush size may well result from differing concentrations of these major plant nutrients. Additionally, the effect of total salt concentration may be playing an important role in causing sagebrush community differences. Total salts tend to be excessive in the valleys and low on the uplands. Soil moisture values in the upland sagebrush sites tend to be higher than those in the bottomland sites. These differences may result from differences in soil texture; Piceance and Forelle loams tend to have higher clay content and better water retaining characteristics. The higher soil moisture levels on the ridges are important for the growth and development of the numerous herbaceous species which characterize the upland sites.

3.3.5.2.3.1 Upland Sagebrush Communities

3.3.5.2.3.1.1 General Location and Distribution

Within the Tract study area upland sagebrush communities occur on broad ridgetops and in clearings within the pinyon-juniper woodlands. This community type usually does not occur on sloping sites.

3.3.5.2.3.1.2 Structure and Composition

The dominant species in the upland sagebrush communities is big sagebrush which occurs at an average density of 10,500 individuals per hectare. Other shrub species appear to be relatively unimportant in these communities. Saplings of pinyon pine and juniper commonly occur, but density values for these species are low. Prickly pear is a common shrub layer component on many of the upland sagebrush types (Appendix IV-B, Tables B-3-12, B-3-13, and B-3-14).

The herb layer is composed of many species which occur at high frequencies. Western wheatgrass, Junegrass, long-leaved phlox, hawksbeard, mariposa lily, clover, and microsteris are all common species which occur at nearly 100 percent frequency. Cover by herbs in these communities averages 45 percent. Mosses and lichens occur only around the bases of the individual sagebrush plants where accumulation of litter and moisture from snow and branch runoff provide suitable habitat (Appendix IV-B, Tables B-3-6 and B-3-7, Stands 8, 11, and 15).

The upland sagebrush sites are quite homogeneous. The average similarity value based on shrub importance values among all sampled upland sagebrush stands was 75 percent. The permanent study site (Plot 3) had an average of 80 percent similarity with other upland sites. Values greater than 80 percent indicate high vegetational similarity. Some of the upland sites are more than 90 percent similar (Table 3-3-8).

Table 3-3-8 MATRIX OF SIMILARITY VALUES[1] FOR SAMPLED UPLAND SAGEBRUSH PLOTS AND STANDS

PLOT/STAND NUMBERS	3-F	3-0	8	11	15
3-F	-				
3-0	89.5	-			
8	89.2	93.4	-		
11	91.8	91.9	90.5	-	
15	53.3	48.0	50.0	49.3	-

PLOT/STAND NUMBERS

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[1] Similarity values are in percents

3.3.5.2.3.1.3 Stability, Diversity, and Succession

The upland sagebrush communities on the Tract constitute an ecologically-stable vegetation type. Several observations point to the long standing presence of this vegetation type. Herb species density in these communities is high (14.1 species per square meter). In this region it appears that considerable time periods are required for species density to reach this level. Factors other than time are also important in determining diversity, but the herb complexity in this vegetation type certainly suggests long-term stability. The growth of sagebrush is such that it is possible to determine approximate ages by counting growth rings in stem cross-sections. The ages obtained for ridgetop plants represent minimal estimates since the plants are multiple-stemmed and as older stems die, new shoots develop. The older sagebrush stems are approximately 50 years old. In addition, sagebrush plants are represented in all size classes, which suggests an equilibrium state with local environmental conditions.

These sagebrush stands do not appear to be successional. In some places pinyon and juniper saplings occur; however, density values for these species are low and suggest only occasional successful establishment. At higher elevations, those above the Tract boundaries, there is a greater component of mixed mountain shrubland species in the sagebrush communities.

3.3.5.2.3.1.4 Environment

The important features of the soil characteristics within this vegetation type have been mentioned in the introductory comments for this section.

The temperature profile for this community type shows more vertical mixing than do the other three major vegetation types. This is reflected by the small differences in temperature at the surface and in free air one meter above the surface. This relationship appears to be the result of the low profile of the vegetation which has little retardant effect on circulating air. In contrast the remaining community types display structural features which channel and buffer moving air. Temperatures in upland sagebrush communities are intermediate with respect to the other three major vegetation types. The greater response of soils at depth is the apparent result of fine-textured soils in combination with good vertical mixing in the air immediately above the surface.

Snow accumulation is important in this community as a source of soil moisture. During the winter snow accumulates to a depth approximately equal to the height of the shrubs. As the snow melts in spring, most of the moisture penetrates into the soil and very little runs off. Because of the deep nature of the loamy soils, soil moisture conditions remain favorable throughout the growing season.

Fires occur occasionally in the upland sagebrush communities. Sites most likely to burn are those which occur as clearings within the woodlands. The incidence of fire is not frequent enough to suggest that it is the factor governing the distribution of this vegetation type.

3.3.5.2.3.1.5 Current Land Use and Management

The upland sagebrush areas are used for livestock grazing. Cattle utilize these areas mostly in May and early June and again in late September and early October. During the major part of the growing season the cattle graze at higher elevations.

Some of the upland sites were chained along with the pinyon-juniper woodlands. The sagebrush does not appear to have been greatly affected by this management approach. No other management practices have been used in the upland sagebrush communities.

3.3.5.2.3.2 Bottomland Sagebrush Communities

3.3.5.2.3.2.1 General Location and Distribution

The bottomland sagebrush communities typically occur on valley floors and alluvial fans of the gulches throughout the Piceance Creek basin. The larger valleys which contain intermittent streams usually are dominated by this vegetation type. Stands of bottomland sagebrush occur at the mouths of most of the small gulches which feed into the major drainages. Narrow strips of sagebrush vegetation follow the intermittent stream channels into the small draws.

Within the Tract study area, the best developed areas of bottomland sagebrush occur in Scandard Gulch and along the West Fork of Stewart Creek.

3.3.5.2.3.2.2 Structure and Composition

The overwhelmingly dominant species in these communities is big sagebrush which provides an average cover of 37 percent and occurs at an approximate density of 18,000 individual plants per hectare (Appendix IV-B, Tables B-3-15 and -16). Prickly pear and winter fat also occur but have low cover and density values. Winter fat reaches its greatest cover and density in the big sagebrush communities. Other shrub species may be encountered in these communities, but they comprise a minor component of the vegetation. Density of sagebrush in the bottomlands is 1.7 times greater than that on the uplands.

The herb layer in the bottomland sagebrush communities is very different from that in the upland communities. The dominant species are cheatgrass, goosefoot, stickseed, and mountain peppergrass which are all characteristic of disturbed sites. The first three species are annuals. Cheatgrass occurred at an average frequency of 100 percent in the sampled bottomland sagebrush stands (Appendix IV-B, Tables B-3-6 and B-3-7, Stands 16 and 19). The most common perennial species was western wheatgrass.

3.3.5.2.3.2.3 Stability, Diversity, and Succession

The widespread distribution and internal homogeneity of this vegetation type suggest its long-term presence in regional vegetation dynamics. All sizes (age classes) of big sagebrush plants occur within the stands (seedlings as well as old, fallen, decomposing stems). The oldest plants (estimated ages based on growth ring counts) are approximately 70 years old. Based on shrub importance value, the average similarity among sampled bottomland sagebrush stands is 85.4 percent. Similarity values among stands ranged from 79 to 91 percent (Table 3-3-9), suggesting that the bottomland sagebrush is a very homogeneous vegetation type. Average similarity between the permanent study site (Plot 4) and other bottomland sagebrush stands was approximately 85 percent.

Apparently, the high salt concentrations which characterize the soil in these communities are detrimental to the development of a diverse understory. Herb species density averaged only 4.8 species per square meter, compared with 14.1 species per square meter in the upland sagebrush communities.

The bottomland sagebrush community does not appear to be successional and shows no developmental relationship coincident with settlement by ranchers in the late 1800's. Agricultural disturbances within these communities seem to favor the development of communities dominated by rabbitbrush rather than by big sagebrush.

3.3.5.2.3.2.4 Environment

The importance of soil nutrients and soil moisture in these plant communities was previously discussed. Other environmental factors are probably less important in determining the distribution of this vegetation type.

The unique feature of this vegetation type is the unusual variation of subsurface temperatures with depths. This type displays a perturbation at depth so that the extreme subsurface is colder than shallow soil areas during both warm and cold weather. This differs from the characteristic pattern of gradual temperature

Table 3-3-9 MATRIX OF SIMILARITY VALUES[1] FOR SAMPLED BOTTOMLAND SAGEBRUSH STANDS

PLOT/STAND NUMBERS	4-F	4-0	16	19
4-F	-			
4-0	87.0	-		
16	79.4	86.5	-	
19	83.0	91.4	85.2	-

PLOT/STAND NUMBERS

[1] Similarity values are in percents

decrease with soil depth in warm weather and the gradual increase of temperature with depth in cold weather. In this vegetation type, the shallow soil areas are either warmer than the surface or about the same temperature. The probable mechanism responsible for this phenomenon is the poor mixing of air above the surface. This effect is produced by dense vegetation which is more than one meter in height in combination with adequate heating of the fine-textured soils.

The lower average air temperatures at one meter, in contrast to upland sagebrush stands, likely result from cold air drainage in bottomland sites. Apparently, the vegetation height is responsible for limiting the effects of cold air drainage to the level of the shrub crown.

Fire probably occurs periodically in the bottomland; however, it does not play an important role in this community type. It is possible that fire may have been used to clear portions of valley bottoms during settlement days since sagebrush is intolerant of burning.

3.3.5.2.3.2.5 Current Land Use and Management

The valley sagebrush communities are currently used for livestock grazing. Cattle utilize the areas in spring and fall, but during summer most of the cattle are found at elevations higher than the Tract.

Some of the bottomland sagebrush stands have been sprayed with herbicide in order to eliminate the sagebrush and encourage the growth of forage species. Most of this activity has occurred on private land outside the Tract boundaries but within the study area. Spraying successes vary and on some sites sagebrush kill has been nearly complete (along Willow Creek). Rabbitbrush appears to be more tolerant of the herbicide and has assumed a dominant role on some sprayed sites.

3.3.5.2.4 Douglas-fir Forests

3.3.5.2.4.1 General Location and Distribution

The Douglas-fir forests are a common vegetation type at higher elevations in the Piceance Creek basin. In the southern portion of the basin they occur primarily on north-facing slopes and individual forests may cover many hectares. In the northwestern portion of the basin stands of Douglas-fir are much less common, and in this region the north-facing sites are dominated by aspen. Transitional stands exist in which both aspen and Douglas-fir occur as co-dominants. At lower elevations (the elevational range in which Tract C-b occurs) Douglas-fir forests are greatly restricted and the stands that do occur are usually composed of only a few trees. Aspen do not occur at these lower elevations.

In the Tract study area small isolated stands of Douglas-fir occur in the draws on the south side of Piceance Creek valley and also to a lesser extent in the small draws which drain into the West Fork of Stewart Creek. In only one or two locations is the tree density great enough to form true forest conditions.

3.3.5.2.4.2 Structure and Composition

The stands of Douglas-fir which occur on the Tract are composed of only a few scattered trees. The stand near the mouth of Sorghum Gulch is a typical example of this vegetation type. At this sampling location only fourteen trees were measured. Several isolated trees occurred along the stream channel, but these were not included in the sample. Tree diameters averaged 26.7 cm (10.5 inches) and ranged from 17.0 cm (6.7 inches) to 37.8 cm (14.9 inches). The larger trees were approximately 18 meters (60 feet) tall. The poorly developed tree layer has done little to modify the understory. However, the areas immediately underneath the trees are covered by fallen needles and cones. Very few herbaceous plants grow in this substrate.

The shrub layer is composed of species which also occur in the mixed mountain shrublands and indicate the similarity of these two vegetation types. Gambel's oak and snowberry were the dominant species and occurred at densities of approximately 8200 and 7500 plants per hectare, respectively (Appendix IV-B, Table B-3-17). The absence of Douglas-fir saplings in the sample suggests that reproductive success for this species is limited in this local area. It is likely that germination and successful establishment of Douglas-fir in these stands occurs only during the most favorable years.

The herb layer in these communities is discontinuous and average herb cover is approximately 25 percent (Appendix IV-B, Tables B-3-18 and B-3-19, Stand 21). Mosses and lichens are common in this community and together they cover nearly 30 percent of the ground layer.

3.3.5.2.4.3 Stability, Diversity, and Succession

Under the existing climatic regime the low elevation Douglas-fir forests appear to be in equilibrium with the environmental parameters. This vegetation type occurs in very restricted sites and sampling data suggest poor reproductive success. It is possible that only a slight climatic change to warmer, drier conditions could cause these communities to shift in the direction of pinyon-juniper woodlands. In the Tract area stands of pinyon-juniper occur which contain a few isolated Douglas-fir trees suggesting the close relationship between these two types at this elevation.

The herb layer species density in the Douglas-fir forests is intermediate to that in other communities and averages 7.5 species per square meter.

3.3.5.2.4.4 Environment

The Douglas-fir forests occur mostly on Rentsac Channery soils on the Tract. The relationship with soil type is probably of secondary importance, and the distribution of this vegetation type is probably controlled more by temperature and moisture than by soil type. The steep north-facing slopes on which these communities occur tend to be cooler and more moist than surrounding sites. Even though these conditions are similar to those encountered in mixed shrub communities, Douglas-fir seems to be restricted to those sites where northerly exposure and steepness are greatest.

Fires do occur in the stands of Douglas-fir but are apparently not a factor controlling their distribution. Burned areas occur mostly in the pinyon-juniper woodlands, and where Douglas-fir occurred adjacent to these sites, they also have been destroyed by fire.

3.3.5.2.4.5 Current Land Use and Management

The Douglas-fir forests are grazed by cattle, but utilization in these areas is low because of the relative sparseness of the vegetation and also the steepness of the slopes. The number of trees is too low to support any lumbering in the area. These areas have not been managed either for tree production or for increased forage production.

3.3.5.2.5 Mixed Mountain Shrublands

3.3.5.2.5.1 General Location and Distribution

Mixed mountain shrublands represent some of the most widespread and abundant plant communities in the Piceance Creek basin and are composed of numerous shrub species which are very important for supporting local mule deer populations. Because there are many shrub species which occur as dominants, the structure and composition of this vegetation type varies considerably depending on the slope, exposure, soil conditions and moisture regime. The most typical stands of mixed mountain shrub include serviceberry, Gambel's oak, snowberry, bitterbrush, and mountain mahogany. On some sites big sagebrush also plays a dominant role in the vegetation. In addition to these common species numerous other shrubs may occur to a lesser extent. Gooseberry and currant, mountain lover, Oregon grape, chokecherry, and skunkbush are all species in this category. Even though typical stands of mixed shrub include many species, there are sites on which communities dominated by a single species develop. Gambel's oak commonly occurs in nearly pure stands which as a vegetation type is known locally as oakbrush. Mountain mahogany also occurs as an overwhelming dominant species on steep slopes which are relatively dry. In some places, serviceberry and big sagebrush occur together as community dominants. The most diverse types of mixed shrublands tend to be located on steep north-facing slopes and usually occur at lower elevations or on more exposed sites than either aspen woodlands or Douglas-fir forests. Shrub-dominated communities, however, are not restricted to those steep slopes, and commonly they occur in some form on ridgetops and southerly-facing slopes at higher elevations. There seems to be a very well-pronounced relationship between the compositional character of the mixed shrub community and the topographic feature on which it develops. The mixed mountain shrub communities on the Tract study area are limited in distribution and occur mostly on northerly-facing slopes.

3.3.5.2.5.2 Structure and Composition

The mixed shrub communities are composed of numerous shrub species (Gambel's oak, serviceberry, mountain mahogany, chokecherry, juneberry, snowberry, and Oregon grape) which comprise typical stands of mixed mountain shrublands. The communities show stratification even among shrub species. The vegetation canopy is composed primarily of larger shrub species (Gambel's oak, serviceberry, and mountain mahogany). However, in some places snowberry forms a nearly continuous layer in the understory (Appendix IV-B, Table B-3-20).

Herb-species composition is varied and includes numerous species characteristic of more mesic vegetation types (Watson's beardtongue, fairy candelabra, pasque flower, and sugar bowls). Low growing shrub species like mountain lover and Oregon grape are also common in the herb layer (Appendix IV-B, Tables B-3-18 and B-3-19, Stand 29).

In addition to the larger stands of mixed shrublands small pockets of this vegetation type occur in the numerous gulches which are common on the Tract. These areas are varied in composition. In many locations small groves of Gambel's oak occur at the upper ends of the lateral gulches which feed into the major drainages of the Tract. At other sites patches of chokecherry occur in these gulches. Many species characteristic of the mixed shrublands occur along the intermittent stream channels forming miniature isolated patches of mixed shrublands. Even though these areas are small, they provide important habitats for wildlife species.

A somewhat different form of mixed shrubland occurs on the ridge immediately west of Little Scandard Gulch. In this community sagebrush, serviceberry, and bitterbrush occur as dominant species.

This form of mixed shrubland is more common at higher elevations, especially on the ridgetops. In many ways it represents a transitional type between upland sagebrush and typical mixed-mountain shrub.

3.3.5.2.5.3 Stability, Diversity, and Succession

The mixed shrub communities in their typical form represent stable communities unlikely to change as a result of succession. The large number of shrub species which characterize this vegetation type provide an element of stability lacking in low diversity shrub communities. In the case of the mixed shrublands on the Tract, the diversity of shrub species could be very important, especially if one of the dominant species was found to be intolerant of industrial development. Where diversity is higher, a greater resiliency potentially exists.

3.3.5.2.5.4 Environment

The environmental characteristics in the mixed shrub communities provide some of the most favorable conditions for plant growth within the study area. The soils are mostly of the Redcreek-Rentsac type, but these appear to have been locally modified by the vegetation and are therefore considerably different than these same soil types developed in pinyon-juniper woodlands. Snow has a tendency to collect on these sites, and slow melting in the spring allows good percolation. Because of the north-facing slope aspect, soil moisture remains at more favorable levels throughout the growing season. Better moisture conditions promote increased production which eventually results in higher soil organic matter content.

Fire does not seem to be an important factor in these communities. Some evidence of fire has been noted, but it does not appear to play an important role in determining the distribution of the mixed shrublands.

3.3.5.2.5.5 Current Land Use and Management

The mixed shrublands are currently used as livestock grazing areas during the summer months. No management practices have been employed in these communities.

3.3.5.2.6 Bunchgrass Community

3.3.5.2.6.1 General Location and Distribution

The bunchgrass communities occur primarily on steep talus deposits on the sides of the major valleys. Topographically they occupy intermediate positions between pinyon-juniper woodlands (located above the talus slopes) and bottomland sagebrush, greasewood, or rabbitbrush communities (located below the talus slopes). Bunchgrass communities also occur near the existing main entrance to the Tract (P-L Ranch) along Piceance Creek. In West Fork, Stewart Gulch these communities occur as narrow bands between the bottomland sagebrush and pinyon-juniper woodlands.

3.3.5.2.6.2 Structure and Composition

The shrub layer in the bunchgrass communities is poorly developed and total density is approximately 2600 shrubs per hectare (Appendix IV-B, Table B-3-21). Along Piceance Creek (Stand 20) the predominant shrub species are shadscale and four-winged saltbush. It is interesting that saltbush occurs on these sites, and its presence suggests above-normal salt concentrations in the soil. High salt concentrations characterize the alluvial fan deposits which occur immediately below Stand 20. It is possible that the determining factors causing the saline conditions in those communities may also be influencing the talus deposits.

Herb layer cover in the bunchgrass communities averages approximately 30 percent. The dominant herb species in these communities is Indian ricegrass with a 90 percent frequency. This species is widespread throughout the Tract area, but it reaches its maximum development in these communities. Other common herb layer species include wild buckwheat, cheatgrass, and brickelbrush. In the ground layer 55 percent of the area is covered by bare soil and rock; accumulated plant litter provides only 35 percent cover (Appendix IV-B, Tables B-3-6 and B-3-7, Stand 20).

3.3.5.2.6.3 Stability, Diversity, and Succession

The bunchgrass communities which occur on the talus slopes represent ecologically stable communities which are unlikely to be replaced by any other vegetation type. The species which grow on these sites are adapted to the extreme environmental characteristics and unstable soil conditions. Species density in these communities is low and averaged only 5.5 species per square meter.

The bunchgrass communities developed in burned-over areas are successional and will eventually be replaced by pinyon-juniper woodlands or upland sagebrush communities.

3.3.5.2.6.4 Environment

The steep talus slopes where the bunchgrass communities occur present some of the most severe environmental conditions in the area. Many of these communities have south-facing exposures which tend to be warm in the winter and hot in the summer. The sparse bunchgrass cover allows penetration of solar radiation to the soil surface during the day and also allows substantial re-radiation of long-wave radiation during the night, thereby causing considerable daily temperature fluctuations. The coarse soils have poor water retaining properties which, along with high growing season temperatures, tend to increase evaporative losses. These communities occur mostly on Rentsac Channery and Rentsac-Redcreek soils. These are mostly light-to-medium-textured soils with sufficient nutrient levels except for phosphorus and potassium which may be present in low or deficient amounts.

The bunchgrass communities are mostly snow-free in winter since the south-facing slopes melt free of snow in a few days. Fire does not play a significant role in the bunchgrass communities which occur on the talus slopes. Indian ricegrass, however, does respond favorably to burning, and on some sites in burned pinyon-juniper woodlands it assumes dominance under post-fire conditions.

3.3.5.2.6.5 Current Land Use and Management

The bunchgrass communities are currently used for livestock grazing. Utilization is mostly restricted to late fall or early winter periods. Sparseness of the vegetation, limited areal extent, and the steepness of the slopes make these areas less important to livestock than the areas containing more widespread native vegetation types. These communities are not being managed for forage production.

3.3.5.2.7 Marshlands

3.3.5.2.7.1 General Locations and Distribution

In this semiarid region of western Colorado aquatic environments are very limited in extent, especially at elevations below 7000 feet. The most commonly encountered water bodies in the area are small reservoirs created either for stock-watering or irrigation purposes. In places where the water supply is constant and standing water is shallow, marshes have developed. These communities are regionally uncommon and occur only on floodplains of major drainages. Within the Tract study area several small marshes occur. However, none occur within the Tract boundary. Two large marshes (4 and 5 hectares) occur along Piceance Creek approximately 3 and 6 kilometers upstream from the main entrance to the Tract. A third, smaller marsh (2 hectares) occurs along Willow Creek, approximately 4 kilometers upstream from its point of confluence with Piceance Creek.

3.3.5.2.7.2 Structure and Composition

The vegetation in the marshes is composed primarily of perennial, herbaceous aquatic and semi-aquatic plants. A few willows occur, but these are small and inconspicuous. The dominant species include cattail, common reed, and numerous species of sedges and rushes.

3.3.5.2.7.3 Stability, Diversity, and Succession

The dominant species which occur in the marshes are adapted to the saturated soil conditions characteristic of these areas. As long as the environmental conditions remain wet, the marshes will continue to persist with few noticeable changes in vegetation structure. If, however, the sites were to dry out, the marshes would be replaced by a more mesic vegetation type such as a sedge meadow. The dominant aquatic species characteristically become rapidly established in uncolonized wet areas. Cattails, especially, have small, light, wind-blown seeds which are produced in abundance. Because of the rapidity with which these communities become established and well-developed, it is difficult to determine how long the marshes have dominated the sites within the study area. It is possible that these marshes have developed since settlement times as a result of ponding of overlandflow irrigation waters. If the sites have always been water collection areas, then the marshes are much older.

3.3.5.2.7.4 Environment

Because of the standing water, the environmental conditions in the marshes are considerably different from those in surrounding areas. Soils are continually saturated, and because of the great amount of unutilized herb production, soil organic matter concentrations are high. Other important factors in surrounding communities such as precipitation, atmospheric moisture, and wind are relatively unimportant in the marshes.

3.3.5.2.7.5 Current Land Use and Management

The marshes along Piceance Creek occur in non-fenced areas adjacent to agricultural meadows and pastures. Consequently, these areas are utilized by cattle during the winter months when livestock are kept in these lower valley meadows. Much of the marsh vegetation is consumed annually or trampled by the grazing livestock.

3.3.5.2.8 Riparian Communities

3.3.5.2.8.1 General Location and Distribution

The riparian communities are located along the sides of the major streams in the area. Within the study area the best developed riparian areas are along Piceance Creek, Willow Creek, and the lower portions of Stewart Creek. Within the Tract boundary there are no riparian areas.

3.3.5.2.8.2 Structure and Composition

The vegetation along the streams is composed of sedges, rushes, horsetails, and species of grasses (Agrostis alba, Phleum pratense, Beckmannia syzigachne). Other stream side species include marsh elder, checker mallow, nettle, Nuttall's sunflower, and Canada goldenrod. Willows occur to a limited extent; most of the individuals are small and isolated. The riparian vegetation is mostly restricted to stream trenches except in those areas where the banks slope gently to the stream bed. The riparian communities along Piceance Creek are bordered by large meadows. The separation of the meadows and riparian communities is indistinct and many semiaquatic species occur in the moist agricultural meadows. In other stream side areas the riparian communities exist as narrow bands immediately adjacent to the streams.

3.3.5.2.8.3 Stability, Diversity, and Succession

The riparian vegetation constitutes a stable community maintained by relatively constant stream flow. The species composition in these communities is relatively constant; variation from site to site is low. In many places the stream side vegetation has been altered because of irrigation practices. Recovery from disturbance is rapid, primarily because of the favorable moisture conditions associated with these communities. Construction of irrigation ditches has done much to increase the extent of this vegetation type, since the environmental conditions along the ditches are much the same as those along the streams.

3.3.5.2.8.4 Environment

The environmental conditions along the stream are very favorable for plant growth. Moisture is present in abundant amounts, and in some cases saturated soil conditions may limit species diversity by allowing only aquatic species to grow. Soil nutrients are plentiful, and irrigation return flows enrich the naturally high nutrient levels.

3.3.5.2.8.5 Current Land Use and Management

The stream side communities are grazed by livestock, with utilization concentrated mostly in the winter months. Most of the grasses, forbs, and some of the smaller willows are annually consumed by the cattle. The livestock also affect the vegetation by trampling, which can be substantial, especially in the soft, wet soils.

3.3.5.2.9 Great Basin Wild Rye Communities

3.3.5.2.9.1 General Location and Distribution

After the arrival of the first ranchers in the Piceance Creek basin region, reports of grasses taller than a horse and rider filtered back into the early settlements. This grass most likely was Great Basin wild rye which prior to settlement had occurred in dense stands on the floodplains of larger streams. Many of the areas formerly dominated by Great Basin wild rye have been converted into agricultural meadows and pastures, and only a few areas of this vegetation type remain. The valley floors of the major streams consist of three different land forms, alluvial fans, floodplains, and stream channels or trenches. These land forms each support different vegetation types. However, these types intergrade and overlap slightly.

Depending on soil salt concentration, the alluvial fans support either big sagebrush (intermediate salt levels) or greasewood (higher salt concentrations). The stream trenches support narrow bands of lush, semi-aquatic vegetation, and the flat floodplains originally supported Great Basin wild rye communities. Remnants of this original pattern of vegetation along areas like Piceance Creek can still be found along the upper reaches of the stream about six kilometers west of Rio Blanco.

On the Tract study area stands of Great Basin wild rye are restricted to small floodplain areas along Willow Creek and the East Fork of Stewart Gulch. These locations likely have never been plowed or improved for irrigation, and for these reasons the wild rye has persisted.

3.3.5.2.9.2 Structure and Composition

The dominant species in these communities is Great Basin wild rye, which occurs as tall, robust clumps. This species is non-rhizomatous and consequently it does not produce a continuous cover. However, where the large clumps occur, the cover is dense. Other common species include cheatgrass and mountain peppergrass. Few shrubs occur in these communities, but big sagebrush plants are occasionally encountered.

3.3.5.2.9.3 Stability, Diversity, and Succession

If undisturbed, the Great Basin wild rye communities show considerable stability. Mention of their occurrence by early settlers and land surveyors indicates their presence as a community type in the late 1800's. The individual grass clumps appear to be long-lived, and reproduction and seedling establishment attest to the continued success of the dominant species. The original extent of these communities has been considerably reduced because of their location on arable floodplain sites. No successional changes have been noted in these communities, and they appear to be the ultimate plant community which naturally develops on the floodplain sites.

3.3.5.2.9.4 Environment

The Great Basin wild rye communities occur on medium textured alluvial soils, primarily of the Glendive loam type. These soils are saline due to excessive amounts of sulfate and sodium. Great Basin wild rye is apparently adapted to these salty conditions and is not eliminated from saline sites until salt levels are considerably higher. The Glendive soils have high levels of nitrogen, phosphorus, and potassium, and of measured nutrients only zinc is deficient.

3.3.5.2.9.5 Current Land Use and Management

The Great Basin wild rye communities are used as grazing areas mostly in the winter. The tall grasses are rather coarse and relatively unpalatable, but they are utilized to some extent by cattle.

3.3.5.2.10 Rabbitbrush Communities

3.3.5.2.10.1 General Location and Distribution

In the Piceance Creek basin two species of rabbitbrush are commonly encountered (*Chrysothamnus nauseous* and *Chrysothamnus viscidiflorus*). The latter is more common at higher elevations where it occurs as a sub-dominant species in upland sagebrush communities and mixed mountain shrublands. It very rarely attains large size or community dominance and does not occur in pure stands. Rubber rabbitbrush is a much more common species at lower elevations and rarely occurs in abundance in upland plant communities. It is frequently encountered in chained rangelands, but in these areas it does not assume community dominance. On floodplains and valley floors this species occurs at high densities and forms communities in which few other shrub species occur. The distribution of this vegetation type in the Tract area is restricted to floodplain areas which have apparently been disturbed in some manner since settlement times. The best development of rabbitbrush occurs at the mouth of the West Fork of Stewart Gulch. Other small stands of this community type occur elsewhere in the Stewart Creek drainage and also in the upper portions of Willow Creek valley.

3.3.5.2.10.2 Structure and Composition

The shrub layer of the communities is dominated by rubber rabbitbrush which has an average cover of 43 percent and occurs at approximate densities of 11,000 shrubs per hectare (approximately equal to one shrub per square meter). The only other shrub species which occurs in those communities is big sagebrush (Appendix IV-B, Table B-3-22).

The herb layer is composed primarily of mountain peppergrass (100 percent frequency), western wheatgrass (95 percent frequency), and cheatgrass (95 percent frequency). In addition to these three species numerous other weedy species occur (Appendix IV-B, Tables B-3-6 and B-3-7, Stand 17). The herb layer species composition in these communities is very similar to that encountered in the valley sagebrush communities and suggests a relationship between these two types. Additionally, the presence of introduced annual weed species suggests grazing disturbances.

3.3.5.2.10.3 Stability, Diversity, and Succession

Based on observations of vegetation patterns in bottomlands within the study area, it appears that rabbitbrush communities constitute a successional vegetation type rather than a stable community. In some areas boundaries of rabbitbrush communities are defined by livestock fences, suggesting the development of this type in response to agricultural activities. The rabbitbrush appears to be developed on sites which were previously covered by valley sagebrush communities.

Successional changes may be expected in the rabbitbrush communities if current grazing practices were to be discontinued. It is possible, however, that the disturbances which allowed the development of the rabbitbrush caused significant enough changes that valley sagebrush communities may not recover on these sites even if grazing were to be discontinued.

3.3.5.2.10.4 Environment

Environmental conditions in the rabbitbrush communities are very similar to those in the valley sagebrush sites. Both of these communities occur on Glendive soils which contain excessive amounts of sodium and sulfate. Soil nutrients are present in normal or above-normal amounts, and zinc is the only nutrient which exhibits a deficiency.

Fire may play a role in the establishment of rabbitbrush communities. Sagebrush is intolerant of fire, and it may be possible that rabbitbrush recovers more quickly on burned sites.

3.3.5.2.10.5 Current Land Use and Management

The rabbitbrush communities are used for livestock grazing, but they have not been managed for range improvement.

3.3.5.2.11 Greasewood Communities

3.3.5.2.11.1 General Location and Distribution

Throughout western Colorado, greasewood communities characteristically occur on alluvial deposits which usually contain high concentrations of soil salts. Extensive areas of greasewood and saltbush occur in the cold, salt-desert regions of northwestern Colorado. The overall range of this community extends into the Piceance Creek basin region, but here, it is restricted to valley bottoms and alluvial fans where local salt levels are high. In the Tract study area greasewood communities are restricted to alluvial fans along Piceance Creek. Isolated individuals occur elsewhere on the Tract, but greasewood community development is restricted to these sites.

3.3.5.2.11.2 Structure and Composition

The species composition in the greasewood communities strongly reflects the intensive grazing utilization which they receive. The greasewood stands are located on the fenced portions of the Piceance Creek floodplain where livestock are wintered. Heavy grazing and trampling cause continued disturbances which provide favorable conditions for the growth of weedy species.

The dominant species in these communities is greasewood which provides an average cover of 27 percent and occurs at a density of approximately 5900 individuals per hectare (Appendix IV-B, Table B-3-23). The shrub layer is relatively open and the individual shrubs tend to grow in clumps rather than to form a continuous canopy. Rubber rabbitbrush occurs as a secondary dominant species, but it is far less abundant than is greasewood.

The herb layer is composed of relatively few species, a situation which is most likely related to disturbance and high soil salt-concentrations. The most common herb species are crested wheatgrass and cheatgrass, both of which are introduced species. The crested wheatgrass was probably seeded into this area in order to provide more forage for cattle. Total herb cover was about 43 percent and was mostly provided by the two dominant species (Appendix IV-B, Tables B-3-6 and B-3-7, Stand 18).

3.3.5.2.11.3 Stability, Diversity, and Succession

The greasewood communities constitute an ecologically stable, vegetation type in the Tract study area. The environmental conditions under which these communities grow are such that few other species can successfully compete with the community dominants. Even though herb species density is very low (3 to 4 species per square meter), these communities demonstrate considerable resiliency and tolerance of continued heavy utilization and disturbance. The stands of greasewood which occur within the area most likely have been growing on these sites since pre-settlement days. Individual plants have matured and died during this time interval, but the basic appearance of these communities apparently has not been altered.

3.3.5.2.11.4 Environment

The greasewood communities occur on Rivra loam soils which are medium-textured, basic and characterized by excessive amounts of nitrates, sulfates, and sodium. Excessive levels of these nutrients are deleterious to plant growth and only certain species are adapted for growth under these conditions. The high salt levels appear to be caused by runoff and its associated sediment load and associated salts. These materials are deposited on the fans. Rate of runoff and low soil permeability prohibit deep soil wetting and leaching of salts into deeper soil strata. Salts concentrate in the upper soil levels as the moisture evaporates from the surface. In addition, remaining salts, deposited earlier in the development of the alluvial fan, are carried upward to the surface by capillary action. Greasewood plants are phreatophytic, which means they tap the water supply at the capillary fringe of the ground water table. By being tolerant of the salty conditions, these plants are assured of a continuous water supply throughout the growing season. Surface salt concentrations may also be increased by leaching of the litter (dead leaves and twigs) which fall from the greasewood plants.

Other environmental factors appear to be less important in the growth of these communities. Soil moisture is important for the herbaceous species and tends to be sufficient early in the growing season.

The species in the greasewood communities are intolerant of fire so that when fires occasionally occur they cause considerable damage. No evidence of fire in the greasewood communities has been noted within the Tract areas.

3.3.5.2.11.5 Current Land Use and Management

The greasewood communities are used as grazing areas during the winter months. In addition to providing limited forage the tall shrubs also provide some protection from winter winds. The presence of crested wheatgrass in these communities suggests some range-improvement seeding; however, these communities apparently have not been otherwise managed for range improvement.

3.3.5.2.12 Agricultural Meadows

The agricultural meadows in the Tract area are restricted to floodplain areas along the major streams. These communities are composed primarily of alfalfa and introduced pasture grasses. The areas are used for hay production during the summer months when cattle are kept on native summer rangelands. During winter months the agricultural meadows are used as grazing areas.

The primary non-industrial occupation within the Tract area is cattle ranching. The agricultural meadows form an important link in total nutrient cycling and energy flow in the livestock-vegetation system. Irrigation waters from Piceance Creek are used to increase hay production in the floodplain meadows. Usually only a single cutting of hay is produced and stacked for winter feeding to cattle. Regrowth of hay species is left standing in the fields and is utilized by livestock when they are returned to the lower valley for the winter. Limited areas of native vegetation (marshes, riparian communities, greasewood, and sagebrush communities) which occur on the floodplain pasture areas are also utilized by cattle during the winter months. Little, if any, of the hay crop is exported from the system. Most of the year's production is used to sustain cattle herds through the winter months. Nutrients and unassimilated materials are therefore retained in the system in the form of cow dung. The final products of the system are market cattle. Individuals lost to natural causes return to the system via decomposition.

During the summer cattle graze on native vegetation at higher elevations where energy flow and nutrient cycling follow patterns characteristic of natural systems. The cattle are dependent on native grass and forb production and recycle nutrients through elimination of non-utilized materials and through death and decomposition.

3.3.5.2.13 Annual Weed Communities

3.3.5.2.13.1 General Location and Distribution

The annual weed communities comprise a somewhat artificial vegetation type which develops on disturbed sites. Disturbances stem from recent industrial development activities (well drilling platforms and access roads) and ranching activities (stock holding and ranchyard areas). Location of these areas follows no pattern, and as might be expected, the appearance of the vegetation which develops on disturbed sites varies considerably from site to site.

3.3.5.2.13.2 Structure and Composition

The vegetation on the disturbed sites is composed primarily of annual weeds. On some sites perennial grasses have become established, but they currently occur in limited amounts. Shrubs are generally absent from the disturbed sites; however, an occasional individual may be encountered. Dominant species on these sites include annuals such as cheatgrass, white pigweed, summer cypress, tumble mustard, Russian thistle, and goosefoot. Western wheatgrass and Indian ricegrass are the most commonly encountered perennial grasses. A total of 39 species was encountered in sampling the disturbed sites (Appendix IV-B, Tables B-3-18 and B-3-19, Stands 22 - 28).

3.3.5.2.13.3 Stability, Diversity, and Succession

The annual weed communities represent the first successional vegetation stages which develop on disturbed sites. In this regard the communities are ecologically unstable and are changing in the direction of equilibrium vegetation types. The final vegetation type which will eventually occupy these sites is primarily determined by the surrounding vegetation. Disturbed sites in the valleys will most likely support sagebrush communities while upland sites will probably develop as pinyon-juniper woodlands. The transition back to stable communities will require a long period of time. Re-establishment of pinyon-juniper woodlands may take as long as 200 years. Because of reduced complexity, shrublands may require only 60 to 70 years to reach stable conditions.

Species density in the disturbed sites was low and averaged only 4.2 species per square meter in the sampled stands.

3.3.5.2.13.4 Environment

Environmental conditions in the annual weed communities are harsh and not conducive to plant growth. Soil characteristics have been altered by disturbance and on some sites coarse subsurface materials have been brought to the surface. Soil surface temperatures fluctuate daily over wide extremes owing primarily to a poorly developed vegetation canopy and lack of plant litter. Soil organic matter content is low but will increase as the successional sequence progresses.

3.3.5.2.13.5 Current Land Use and Management

Cattle utilize these areas incidentally as they graze throughout the native plant communities.

Management has been limited to reclamation and revegetation of some of the sites.

3.3.5.2.14 Aquatic Plant Communities

3.3.5.2.14.1 Lentic

Ponds and lakes are forms of lentic communities. In the ponds near the Tract organic content is high and the bottoms of the ponds are covered with a fine sedimentary ooze. Pondweeds (*Potomogeton* spp.) are found in most of the ponds. Because the ponds are maintained by ranchers, they have not gone through the successional stages as quickly as might be expected.

3.3.5.2.14.2 Lotic

Rivers, streams, seeps, and springs are all forms of lotic communities. Piceance Creek supports local concentrations of watercress which is one of the commonly encountered species in the stream. Piceance Creek is greatly affected by irrigation diversion. However, in the spring snow runoff swells the stream and increases the silt loading. Cold water temperatures and the high turbidity tend to retard the growth of plants and algae. By late summer, however, warmer water temperatures encourage the growth of the aquatic plants which grow in the stream.

3.3.5.3 Similarities Among Vegetation Types

The vegetation types which occur on the Tract are primarily characterized by the shrub layer components. Approximately 40 percent of the Tract study area is covered by pinyon-juniper woodland.

Comparisons among the vegetation types, however, are difficult based only on tree parameter estimates, since most of the vegetation types lack trees. Shrubs occur in nearly all of the types except for the moist areas in the valleys and disturbed sites. Since the shrubs are so widespread, shrub importance value (Table 3-3-10) was used as the basis for comparison of the study area vegetation types. Importance values were used to calculate similarity indices (Table 3-3-11) for all possible stand comparisons exclusive of those types where shrubs were lacking. Similarity index values may theoretically range between 0 and 100 percent. Two stands which have no species in common have no similarity, while two stands composed of only the same single species would have a similarity index of 100 percent. Within the study area similarity values ranged from zero to 93.4 percent. The Douglas fir forest stand had no sampled shrub species in common with the rabbitbrush, greasewood, bunchgrass, and one of the bottomland sagebrush stands. The greatest measured similarity between the Douglas fir forest and other vegetation types was with a stand of pinyon-juniper located on a north-facing slope (Stand 13). The greatest measured similarity was between two stands of upland sagebrush vegetation. This type is very homogeneous and is composed primarily of big sagebrush and few other species. The monospecific dominance by big sagebrush allows the measured similarity to approach the theoretical maximum. Prickly pear cactus, a common component within this type, occurs in consistently similar amounts which also increases the total similarity. Other very high similarity values were measured between upland sagebrush stands, between bottomland sagebrush stands, and comparisons of bottomland and upland sagebrush stands. All of these high values can be attributed to the overwhelming dominance of big sagebrush in these types.

Intermediate similarity index values were obtained for the pinyon-juniper woodlands and chained rangelands. These types are characterized by numerous shrub species which vary in importance from site to site within the study area. In some locations, bitterbrush occurs as the dominant shrub species, while in other areas mountain mahogany, serviceberry, snowberry, or oak may be the leading dominant. The presence of these species is quite consistent from site to site, but their importance in a given stand is highly variable both in the woodlands and in the chained rangelands.

Low similarity values were also obtained in comparisons between rabbitbrush communities, greasewood communities, and bunchgrass communities with all of the upland vegetation types. These low values are attributable to the fact that the shrub species in these bottomland and slope communities do not occur to any great extent elsewhere within the study area.

Average similarity values (Table 3-3-12) were calculated by deriving the arithmetic mean of the similarity indices for a single stand compared with all other stands. The stand which had the greatest average similarity was Stand 6, one of the intensive pinyon-juniper woodland study plots, with a value of 48.4 percent. The stand with the least average similarity was

Table 3-3-10 SHRUB LAYER SPECIES IMPORTANCE VALUES^1 (PERCENTS) FOR ALL SAMPLED PLOTS AND STANDS^2 EXCLUSIVE OF DISTURBED SITES FOR THE 1975-1976 SHRUB SAMPLING PERIOD

	1*	2*	3*	4*	5*	6*	7	8	9	10	11
Amelanchier spp.	10.1	8.1	8.0		8.6	27.0	18.5			9.9	2.6
Artemisia tridentata	129.8	42.6	245.5	247.4	78.2	177.1	78.5	247.3	49.8	124.5	235.9
Artemisia sp.		0.8									
Atriplex canescens											
Atriplex confertifolia											
Ceratoides lanata	0.8	10.8		27.3							
Cercocarpus montanus	24.7	13.4			59.6		13.9		2.3		
Chrysothamnus nauseosus	23.8	79.6	5.2	7.2	5.5	9.1	5.9	7.5		9.0	
Chrysothamnus viscidiflorus	2.7	3.6					7.5	5.9	15.8	2.3	
Gutierrezia sarothrae	8.9		0.4								
Juniperus osteosperma	10.0	53.0	6.4		9.4	18.0	23.3	10.9	14.8	16.6	7.1
Juniperus scopulorum	6.2			1.3	3.4				4.6	7.9	6.9
Opuntia polyacantha	1.2		14.6	14.0	5.5	22.0	17.5	19.8	19.4	6.2	24.9
Pachystima myrsinites											
Pinus edulis	22.0	40.8	20.1		66.1	34.0	12.6	8.6	41.8	28.9	21.5
Purshia tridentata	49.8	36.8			24.6	1.7	11.0		145.6	86.5	2.2
Quercus gambelii											
Ribes cereum											
Ribes inerme											
Rosa woodsii											
Sarcobatus vermiculatus											
Symphoricarpos orephilus	9.4	10.2		2.9	38.6	11.2	104.2		5.8	9.9	
Tetradymia canescens											

* Intensive study plots

Table 3-3-10 (Continued)

	12	13	14	15	16	17	18	19	20	21	29
Amelanchier spp.	35.0	34.2	31.3	49.2							70.3
Artemisia tridentata	113.1	14.9	3.2	133.8	225.6	28.6	7.2	261.8	31.7		40.0
Artemisia sp.											
Atriplex canescens									33.8		
Atriplex confertifolia									193.4		
Ceratoides lanata									10.7		
Cercocarpus montanus		24.9	49.1							7.4	10.5
Chrysothamnus nauseosus		4.9	1.6		49.8	271.4	46.9	30.0	3.4		
Chrysothamnus viscidiflorus	46.6	15.7	22.9	58.8					18.6		33.5
Gutierrezia sarothrae											
Juniperus osteosperma	7.5	4.1	29.2								0.8
Juniperus scopulorum		7.4								16.0	6.8
Opuntia polyacantha	28.3		1.6	2.6	16.4			7.0	4.7		3.3
Pachystima myrsinites											4.3
Pinus edulis	49.6	11.0	38.3	7.7						11.8	16.3
Purshia tridentata	5.7	23.5	17.9	1.2							5.1
Quercus gambelii										134.7	
Ribes cereum										24.0	1.1
Ribes inerme											
Rosa woodsii											
Sarcobatus vermiculatus							242.7		3.4		
Symphoricarpos oreophilus	14.2	113.9	100.9	41.6						106.1	105.4
Tetradymia canescens			4.0	5.0							2.6

[1] Importance value = Relative cover + Relative density + Relative frequency

[2] See Table 3-3-5 for stand number-vegetation type conversion

Table 3-3-11 MATRIX OF SIMILARITY VALUES[1] FOR SAMPLED VEGETATION STANDS[2]

PLOT/STAND NUMBERS	1	2	3	4	5	6	7	8	9	10	11
1	-										
2	56.5	-									
3	57.0	27.4	-								
4	47.7	21.2	88.2	-							
5	62.3	51.5	41.1	31.1	-						
6	64.4	41.2	77.1	67.1	51.4	-					
7	51.8	43.6	41.8	33.8	61.1	54.6	-				
8	53.1	24.4	93.4	89.5	35.7	74.6	42.4	-			
9	49.4	48.9	30.3	22.7	47.5	41.8	40.4	31.5	-		
10	81.4	51.4	56.8	47.4	58.0	68.9	51.0	53.3	66.3	-	
11	56.9	25.3	93.2	83.7	40.2	77.3	40.2	90.5	34.9	57.2	-
12	57.2	39.5	54.1	43.3	53.6	72.2	54.0	51.6	48.6	61.2	57.1
13	37.2	31.2	14.3	8.0	44.6	24.9	65.7	12.8	27.3	29.3	13.9
14	34.3	41.8	13.6	3.1	56.1	32.8	64.7	10.6	33.2	30.6	12.7
15	54.0	21.8	50.7	46.4	45.6	61.2	52.5	50.0	27.6	52.7	49.3
16	54.3	33.5	81.8	83.2	32.5	70.3	36.3	83.2	24.0	49.3	80.7
17	17.5	36.1	11.3	11.9	11.4	12.6	11.5	12.0	9.5	12.5	9.5
18	10.3	18.0	4.1	4.8	4.2	5.4	4.4	4.9	2.4	5.4	2.4
19	51.6	24.2	85.9	87.2	29.7	64.4	30.5	87.3	18.9	46.6	81.0
20	13.3	16.5	13.3	16.8	12.3	13.3	15.8	15.2	17.4	14.0	12.1
21	11.6	9.8	3.9	1.4	20.4	7.7	43.5	2.9	8.2	9.9	6.2
29	34.1	31.5	22.8	14.7	42.2	33.4	67.5	19.5	31.3	31.5	23.1

PLOT/STAND NUMBERS

Table 3-3-11 (Continued)

PLOT/STAND NUMBERS	12	13	14	15	16	17	18	19	20	21	29
12	-										
13	33.3	-									
14	41.6	70.2	-								
15	73.5	38.4	37.8	-							
16	45.9	9.3	4.9	48.2	-						
17	9.5	6.6	1.6	9.5	26.1	-					
18	2.4	4.0	1.6	2.4	18.0	18.0	-				
19	40.0	6.6	2.1	45.5	85.2	19.5	12.4	-			
20	18.3	6.1	8.3	17.6	13.3	10.7	6.2	13.3	-		
21	8.7	57.9	40.0	16.4	2.7	0.0	0.0	0.0	0.0	-	
29	49.1	68.1	65.1	59.5	17.2	9.5	2.4	14.4	17.9	43.8	-

PLOT/STAND NUMBERS

[1] Values are in percents

[2] See Table 3-3-5 for stand number--vegetation type conversion. Plots 1 and 2 are chained rangeland, Plot 3 is upland sagebrush, Plot 4 is bottomland sagebrush, and Plots 5 and 6 are pinyon-juniper woodland.

Table 3-3-12 AVERAGE SIMILARITY VALUES FOR SAMPLED VEGETATION STANDS

	Stand No.	Vegetation Type	Average Similarity (%)
Group 1	6*	Pinyon-juniper Woodland	48.4
	3*	Upland Sagebrush	45.8
	1*	Chained Rangeland	45.5
	11	Upland Sagebrush	45.1
	8	Upland Sagebrush	44.7
	10	Chained Rangeland	44.5
	12	Pinyon-juniper Woodland	43.6
	7	Chained Rangeland	43.2
	16	Bottomland Sagebrush	42.9
	15	Upland Sagebrush	41.0
	4*	Bottomland Sagebrush	40.6
	19	Bottomland Sagebrush	40.3
	5*	Pinyon-juniper Woodland	39.6
Group 2	29	Mixed Mountain Shrubland	33.3
	2*	Chained Rangeland	33.1
	9	Pinyon-juniper Woodland	31.5
	13	Pinyon-juniper Woodland	29.0
	14	Chained Rangeland	28.9
Group 3	21	Douglas fir Forest	14.0
	20	Bunchgrass Community	12.9
	17	Rabbitbrush Shrubland	12.7
	18	Greasewood Shrubland	6.4

* Intensive study plots

Stand 18, a greasewood vegetation stand, with an average similarity of only 6.4 percent. Based on average similarity, the sampled stands can be separated into three general groups (Table 3-3-12). The first group, with average similarity, values ranging from 39.6 to 48.4 percent, are all stands in which big sagebrush occurs in either moderate or high amounts. The group includes all the upland and bottomland sagebrush sites and also those chained rangeland and woodland stands in which big sagebrush is common. The other important feature of this group is the low to moderate occurrence of the mixed shrub species (serviceberry, bitterbrush, mountain mahogany, and snowberry). The stands in group two are characterized by low densities for big sagebrush and also by a large component of the mixed shrub species in the shrub layer. These stands tend to be located on north, northeast, or east facing slopes and appear to be somewhat more moist than the other sampling locations. The third group is composed of those stands which have very little in common with other sites within the area. The dominant species are those which are mostly restricted to a single vegetation type, e.g. rabbitbrush in the rabbitbrush communities, greasewood in the greasewood communities, and shadscale and four-wing saltbush in the bunchgrass community.

In general the most significant factor influencing the similarity of the sampled stands appears to be the abundance of big sagebrush. The stands which had the greatest average similarity were those in which big sagebrush was an important species, but not the overwhelmingly dominant species. Bottomland sagebrush stands tended to have lower average similarities than upland sagebrush stands, owing primarily to the low shrub species diversity in the bottomlands. Since big sagebrush occurs as a dominant in many situations on the Tract, it is not surprising that the stands in which big sagebrush was absent or present in only minor amounts would have low similarity compared with the sagebrush dominated areas.

3.3.5.4 Intensive Study Plot Studies

3.3.5.4.1 Herb Layer Composition

Determination of herb frequencies at each of the intensive study plots has served a dual purpose during the baseline study period. The data from the 25 permanent 1-m^2 quadrats have been useful in describing the structural components of the herb layer within the major vegetation types. Also these plots have provided the base for long-term study of changes in herb layer species composition. Each of the quadrats was sampled both in 1975 and 1976 in order to determine what differences would be recorded during a non-development period.

Several rather interesting differences between the two years can be seen from the data (Appendix IV-B, Tables B-3-24 and B-3-25). Observations were made by the same individual both years. (During actual monitoring conditions, it is probable that different individuals would be responsible for the field sampling, thus introducing greater judgmental errors.)

The data from the two years are quite consistent and for most species the observed frequencies were the same or within one or two observations of being the same. Certain life form groups showed greater consistency than others. Perennial forbs were very consistent between the two samples. For the most part, these plants are large, easily identifiable, and not often confused, except as noted below. Perennial plants which grow from bulbs, mariposa lily, and death camas were very common in 1975 and nearly absent from the sample in 1976, especially at the upland sagebrush site (Plot 3). In Plot 3-0 mariposa lily had a frequency of 100 percent in 1975 and was completely absent in 1976. In 1975 most of the mariposa lily plants occurred as a single leaf and only a small percentage flowered. The differences between the two years may relate to the cooler and more moist conditions which prevailed in spring and early summer of 1975; 1976 tended to be warmer and drier during this period.

Perennial grasses were also quite consistent, especially in cases when the plants had flowering culms. Differences occurred in some samples (e.g., Plot 6) where several perennial grass species occur and few flowering heads were noted.

Most of the observed frequency differences in perennial grasses can likely be attributed to misidentification of vegetative plants. This was especially true for the species of bluegrass (Poa spp.) which are easily overlooked or included with other species when in a vegetative state. Wheatgrasses (Agropyron spp.) on the other hand are more distinctive, and a greater consistency between the two years can be seen for these species.

Annual plants, as a group, showed the greatest differences between the two years, being more frequent in 1975. The individual plants included in this group tend to be very small and diminutive at the sampling locations and may be only 2-5 cm tall. Introduced Eurasian weeds especially goosefoot and tansy mustard were less frequent at nearly all of the sites.

Estimates of total herb cover were comparable (within 1-4 percent) between the two years (Appendix IV-B, Tables B-3-26 and B-3-27) except at the bottomland sagebrush site (Plot 4) where the 1975 cover was greater by 10 percent in the open plot and by 5 percent in the fenced plot. In Plot 4 the herb layer is dominated by cheatgrass, an annual, which was also apparently affected by the dry season. Frequency values for this species were 100 percent in both the fenced and open plots, but the total cover (most of which is provided by cheatgrass) was less in 1976. At the other sampling locations, the herb layer is composed primarily of perennial species which, even though they may be affected by a dry season, still provided approximately the same amount of cover both years.

Species density estimates (the number of species observed per unit area) were greater at nearly all sites in 1975. These differences were slight (ranging from <1 to 1 species per m^2) and most likely can be attributed to decrease in annuals and bulb forming perennials (especially at Plot 3).

Estimates of litter cover were variable between the two years; especially in those plots where mosses are abundant (Plot 4, mostly). Litter cover values were greater in 1976 possibly because the mosses were more dried out than in 1975 and more closely resembled litter than living plants.

In looking for reasons to explain observed frequency differences, it seems that they can be categorized as resulting from environmental influences and judgmental differences. Sampling occurred within a one-week span in June both years (approximately June 20th). In 1975 the growing season was late, and many of the early flowering species were still evident. In 1976, however, the season was earlier, such that by mid-June many of the species had already begun to senesce, especially the native annuals like baby blue eyes. Additionally, a late killing frost in early June apparently affected the basal rosettes of species like hawksbeard and biscuit root such that the leaves for these species were dried and senescent by the time the sampling occurred. Other differences in frequency values are related to misidentification or confusion of morphologically similar species. Species of pussytoes (Antennaria rosea and A. parvifolia), Indian paintbrush (Catilleja chromosa and C. linariaefolia) and knotweed (Polygonum douglasii and P. sawatchense) can be easily confused, especially in vegetative conditions. Similar genera such as fleabane (Erigeron) and aster (Aster), hawksbeard (Crepis) and false dandelion (Agoseris), and baby blue eyes (Collinsia) and microsteris (Microsteris) were also confused, especially in vegetative and early senescent stages.

In using herb species frequencies for monitoring long-term site changes, it is apparent that certain problems (specifically those noted above) must be considered when evaluating yearly differences. Certain species, pairs, or groups which are morphologically similar can be used for monitoring only when field investigators are well-trained in their identification. This sampling program used as a monitoring tool will be useful in evaluating major changes in species composition, but most likely is not sensitive enough to detect subtle changes in the vegetation.

3.3.5.4.2 Shrub Layer Structure and Composition

3.3.5.4.2.1 Frequency

Frequency values for most species were very comparable between the two years (Appendix IV-B, Tables B-3-28 and B-3-29). Approximately 86 percent of the observed values were within plus or minus three plots of occurrence with 26 percent of the observations being the same for both years. Only 9 percent of the observations were equal to or exceeded plus or minus five plots of occurrence. Serviceberry had lower observed frequencies in all but one plot (including both fenced and open plots). Prickly pear also had consistently lower values owing most likely to the fact that this species can be easily overlooked. Overall, 40 percent of the observed frequencies were greater in 1976 and 34 percent were less than those observed in 1974.

3.3.5.4.2.2 Cover Values and Percent Composition

Most sites showed slight increases in cover from 1974 to 1976 with fenced plots in general showing a slightly greater increase (Appendix IV-B, Tables B-3-30 and B-3-31). Estimates in woodland plots were still very low reflecting the greatly reduced woody understory. Plot 6-F (pinyon-juniper woodland) showed a slight reduction between the two years. The only large decrease was in Plot 4-0 (bottomland sagebrush), where big sagebrush cover dropped from 36.8 percent to 29.5 percent. This decrease may possibly be attributed to differences in sampling crews between the two years, since other data (density and frequency) do not show any such decreases.

Percent composition (relative cover) values were quite comparable between the two years suggesting that the sampling sites have been at least internally consistent for the past two years (Appendix IV-B, Tables B-3-32 and B-3-33).

3.3.5.4.2.3 Density

The greatest observed differences in plant density occurred in the bottomland sagebrush community where an approximate one-third increase was noted in the density of big sagebrush (Appendix IV-B, Tables B-3-34 and B-3-35). Increases were noted in both the fenced and open plots suggesting that the differences were not related to fencing effects. Most of the increases were in the smallest height class (25-75 cm). Because of the large number of individuals in this class, the density differences may well relate to sampling judgments. When a large number of plants are to be counted a greater tendency for error exists. Values for other species which were not as abundant were more consistent between the two years. These values were neither consistently higher or lower when all plots were evaluated. Density values for prickly pear and snakeweed were variable owing primarily to the ease with which they may be overlooked. Bitterbrush had higher density values at nearly all locations in 1976. The 1974 sampling crew estimated density on the basis of number of clumps of bitterbrush, while the 1976 crew had a tendency to divide the clumps into several individuals.

Since the shrubs are much less susceptible to yearly environmental fluctuations than are annual plants and some perennial forbs, it is difficult to attribute observed differences to yearly perturbations in temperature and precipitation. The cumulative effect of consistent increases or decreases in these factors would most likely bring about a shift in shrub layer structure and composition; however, this would require a time greater than the two-year baseline period. It appears, then, that the observed differences in shrub cover, density, and frequency result primarily from sampling influences rather than environmental changes. The value of using these parameters for monitoring will come from long-term trend analysis. If changes or trends are noted during the life of the project, these will likely be major changes, since subtle differences will likely be undetected.

3.3.5.4.3 Tree Layer

Tree growth at intensive study Plots 5 and 6 (pinyon-juniper woodlands) was minimal during the baseline period. The largest average increase in diameter at breast height (Appendix IV-B, Table B-3-36) was 7 mm for Utah juniper at Plot 5-F. Expressed in terms of radial growth per year, this value becomes approximately 1.75 mm per year. Growth rate estimates for pinyon pine show very minor differences between the two years of observation. Values ranged from a maximum of 3 mm at Plot 5-0 to an observed decrease of 1 mm at Plot 5-F. Problems associated with repeated measurement of trees, especially those which grow very slowly, most likely are influencing the measured values. All of the trees which were measured were tagged, marked, and then were re-measured two years later at the height where the tag was attached to the tree. Even though these precautions were taken, some diameter values were less in 1976 than in 1974. Utah juniper, because of its shaggy bark, is especially difficult to measure.

The measured values of diameter provide a general estimate of tree growth and even though the mean values are affected by the sampling difficulties, they would seem to be characteristic of the slow-growing tree species on the Tract.

The use of tree diameter comparison for monitoring purposes will have to be limited to trend analysis. Over time, a low yearly increase in diameter would be expected, and only if this trend were to stop completely for several years would an industrial effect be suspected. If an earlier detection of change is of interest, then a more sensitive measure of tree growth must be used.

3.3.5.5. Production Studies

3.3.5.5.1 Herb Production Studies

As mentioned earlier, the study of herbaceous production on Tract C-b during 1976 was increased in terms of the total number of clipped quadrats per site per date and also by increasing the quadrat size at some of the sites. These changes have allowed for a more precise estimate of standing crop at each site for each clipping date. The estimate of yearly production is based on the combined clipping data (the average of clip quadrats from the open, deer-fenced, and livestock-fenced plots) from the month during which maximum current live standing crop was reached. This approach has been shown to provide estimates of yearly production which are less than the actual total net production (Kelly et al. 1974). Based on data from eastern Montana, Kelly et al. found that peak season clip estimates were at least 30 percent lower than values obtained from species summation procedures. The Montana prairie site is more complex taxonomically than are the individual study sites on Tract C-b. Most of the yearly production can be attributed to two or three dominant species which tend to attain peak standing crop at approximately the same time during the growing season. Even though the effect of differential maturation rates may not be as great in floristically less diverse communities, the estimates of aboveground production for Tract C-b are likely to be somewhat lower than the actual values.

3.3.5.5.1.1 Chained Rangelands

Aboveground herb production in the chained rangelands during the 1976 growing season averaged 187±35 kg/ha at Plot 1 and 192±39 kg/ha at Plot 2 (± values are equal to the standard error of the mean). These estimates are based on combined data from the July clip (date of maximum standing crop)(Table 3-3-13). Examination of seasonal changes at these sites reveals that at Plot 1 there are no statistically significant differences among the three treatment plots in the current live standing crop at any of the clip dates (tested using an analysis of variance). At Plot 2 significant differences were recorded between the open plot and deer-fenced plot in both May and July. These differences are of interest since it was the open plot which had the greater standing crop. Also in May there was a significant difference between the livestock plot and the deer-fenced plot with the greater standing crop occurring in the livestock plot. These differences most probably relate to inherent site differences and the variability within the herb layer rather than resulting from the actual fencing treatments. No significant differences among treatments were noted in the standing dead fraction of any of the sampling dates at either Plot 1 or 2 (Table 3-3-14); however, at Plot 1 in both April and August the amount of litter and prostrate dead was significantly greater in the deer-

Table 3-3-13 CURRENT LIVE STANDING CROP AT EACH OF THE INTENSIVE STUDY PLOTS DURING 1976[1]

	$\bar{X}$ ± S.E. (kgm/ha)				
	4/24/76	5/16/76		7/20/76	8/21/76
Plot 1-0	40± 8	64±12	--	200±72	118±28
Plot 1-F	56±14	67±17	--	200±63	193±51
Plot 1-C	64±19	79±20	--	160±50	249±58
Plot 1 (combined)	53± 8	70± 7	--	187±35	187±28
	4/22/76	5/14/76		7/22/76	8/18/76
Plot 2-0	80±37	101±19	--	320±100	168±38
Plot 2-F	23± 7	44±15	--	104±26	120±48
Plot 2-C	28± 8	126±29	--	152±40	129±34
Plot 2 (combined)	44±13	90±13	--	192±39	139±23
	4/23/76	5/15/76		7/20/76	8/20/76
Plot 3-0	91±17	173±40	--	164±10	134±15
Plot 3-F	102±24	170±24	--	269±39	225±37
Plot 3-C	73±16	242±54	--	327±38	221±28
Plot 3 (combined)	88±11	195±24	--	254±21	193±17
	4/23/76	5/15/76	6/17/76		8/19/76
Plot 4-0	16± 4	63±18	100±22	--	93±32
Plot 4-F	14± 6	49±10	97±25	--	27±11
Plot 4-C	16± 5	176±33	142±50	--	198±56
Plot 4 (combined)	16± 3	96±16	113±20	--	75±26
	4/25/76	5/17/76		7/21/76	8/21/76
Plot 5-0	26± 8	42± 8	--	104±26	74±18
Plot 5-F	22± 6	102±39	--	80±20	97±26
Plot 5-C	10± 4	31± 8	--	100±29	37±11
Plot 5 (combined)	19± 4	58±14	--	95±14	69±11
	4/26/76	5/18/76		7/21/76	8/21/76
Plot 6-0	17± 5	112±35	--	95±30	79±32
Plot 6-F	26± 8	124±35	--	132±31	92±20
Plot 6-C	57±12	151±42	--	249±52	339±60
Plot 6 (combined)	34± 6	129±21	--	159±24	169±29

[1] Quadrat size for Plots 1, 2, 5, and 6 equals 0.25 m^2; Plots 3 and 4 equals 0.1 m^2.

n = 15 quadrats; combined n = 45 quadrats.

Table 3-3-14 STANDING BIOMASS AT EACH OF THE INTENSIVE STUDY PLOTS DURING 1976[1]

	$\overline{X}$ ± S.E. (kgm/ha)				
	4/24/76	5/16/76		7/20/76	8/21/76
Plot 1-0	96±45	70±25	--	85±21	88±23
Plot 1-F	363±131	139±45	--	229±125	226±96
Plot 1-C	153± 52	165±75	--	143± 53	245±96
Plot 1 (combined)	204± 51	126±30	--	153± 46	186±46
	4/22/75	5/14/76		7/22/76	8/18/76
Plot 2-0	151±68	46±12	--	139±45	99±33
Plot 2-F	106±42	72±45	--	87±20	92±27
Plot 2-C	106±36	78±22	--	113±27	107±17
Plot 2 (combined)	121±29	65±17	--	113±18	99±15
	4/23/76	5/15/76		7/20/76	8/20/76
Plot 3-0	121±16	108±22	--	203±56	176±73
Plot 3-F	175±20	137±18	--	252±52	217±44
Plot 3-C	232±53	188±41	--	217±29	86±19
Plot 3 (combined)	176±20	145±17	--	224±27	160±30
	4/23/76	5/15/76	6/17/76		8/19/76
Plot 4-0	101±27	87±26	39±10	--	57±16
Plot 4-F	64±13	72±26	47±22	--	46±22
Plot 4-C	55±20	244±78	125±67	--	163±50
Plot 4 (combined)	73±12	134±30	71±25	--	89±19
	4/25/76	5/17/76		7/21/76	8/21/76
Plot 5-0	314±174	63±30	--	65±26	66±23
Plot 5-F	100±37	118±56	--	32±10	46±16
Plot 5-C	22± 9	30± 8	--	42±11	17± 5
Plot 5 (combined)	145±61	70±22	--	46±10	43±10
	4/26/76	5/18/76		7/21/76	8/21/76
Plot 6-0	32±14	29±11	--	37±19	38±22
Plot 6-F	80±23	47±11	--	44± 8	63±25
Plot 6-C	106±27	149±69	--	95±25	161±42
Plot 6 (combined)	73±13	76±25	--	19±12	87±19

[1] Quadrat size for Plots 1, 2, 5, and 6 equals 0.25 m^2; Plots 3 and 4 equals 0.1 m^2.

n = 15 quadrats; combined n = 45 quadrats.

fenced plot when compared with the open plot (Table 3-3-15). Significant differences in the litter and prostrate dead fraction also occurred at Plot 2 in July between the open and deer-fenced plot (the open plot value was higher) and between the deer-fenced plot and livestock plot (the livestock plot was higher). In August a significant difference was noted with livestock plot being greater than the open plot. The differences of Plot 1 suggest that a build up of litter and prostrate dead in the deer-fenced plot may be occurring but at Plot 2, litter differences seem to be more related to variability within the herb layer itself rather than being specifically associated with any of the treatments. Comparison of peak standing crop data from July suggests that no significant difference exists between the herb production of two chained rangeland sites.

3.3.5.5.1.2 Pinyon-Juniper Woodlands

Herb production at the two pinyon-juniper woodland sites was not as consistent as in the chained rangelands. Maximum standing crop at Plot 5 was only 95±14 kg/ha in July, while at Plot 6 the maximum was 169±29 kg/ha in August (Table 3-3-13). Based on a t-test with a 0.05 probability level, these two means are different. However, the data from Plot 6 include standing crop estimates taken from the livestock plot which is more open and has fewer trees than either of the other two clipping locations at Plot 6. This openness is also characterized by a better developed herb layer and a shrub understory dominated by big sagebrush, thus making the understory of the plot quite similar to the upland sagebrush community. If the clipping data from the livestock plots are excluded from the Plot 5/Plot 6 comparison and only data from the open and deer-fenced plots are used, no significant differences exist between either the July or August standing crop estimates. The difference between the livestock plot at Plot 6 and the sampling locations is also reflected in significant differences between this plot and both the open and deer-fenced plots in April, July, and August relative to the current live standing crop. No significant differences in current live standing crop were measured between the open and deer-fenced plots at any of the sampling dates at Plot 6. At Plot 5 no significant differences in current live were noted among the treatment plots at any of the sampling dates.

No clear patterns exist relative to differences in standing dead biomass at the two pinyon-juniper study plots (Table 3-3-14). In April at Plot 5 the standing dead estimate was greater in the deer-fenced plot than in the livestock plot and greater in the open plot than in the livestock plot in August. At Plot 6 significant differences were noted between the standing dead fraction in the open plot and the two fenced plots with the standing dead being greater in both the open and fenced plots. In August the standing dead was greater in the livestock plot than it was in either of the other two plots. All of these differences most likely relate to the variation within the herb layer rather than being manifestations of treatment effects.

Table 3-3-15 LITTER AND PROSTRATE DEAD AT EACH OF THE INTENSIVE STUDY PLOTS DURING 1976[1]

	$\bar{X}$ ± S.E. (kgm/ha)				
	4/24/76	5/16/76		7/20/76	8/21/76
Plot 1-0	99±20	119±24	--	112±33	123±20
Plot 1-F	202±43	137±39	--	194±46	257±60
Plot 1-C	200±71	123±30	--	101±29	233±70
Plot 1 (combined)	167±29	126±18	--	136±22	204±32
	4/22/76	5/14/76		7/22/76	8/18/76
Plot 2-0	165±52	170±24	--	198±29	122±27
Plot 2-F	128±45	125±37	--	68±14	138±44
Plot 2-C	134±31	207±47	--	189±39	258±47
Plot 2 (combined)	142±25	168±14	--	154±19	173±24
	4/23/76	5/15/76		7/20/76	8/20/76
Plot 3-0	114±10	131±14	--	119±15	138±21
Plot 3-F	197±21	198±16	--	239±33	275±30
Plot 3-C	140±16	187±22	--	220±23	238±35
Plot 3 (combined)	150±11	172±11	--	193±16	217±19
	4/23/76	5/15/76	6/17/76		8/19/76
Plot 4-0	129±47	166±36	122±34	--	275±65
Plot 4-F	96±10	125±22	137±35	--	101±20
Plot 4-C	290±98	209±49	110±21	--	235±57
Plot 4 (combined)	172±38	167±22	123±18	--	204±31
	4/25/76	5/17/76		7/21/76	8/21/76
Plot 5-0	147±48	112±28	--	122±50	87±23
Plot 5-F	144±66	281±105	--	69±22	112±32
Plot 5-C	33±11	43±18	--	73±19	34±11
Plot 5 (combined)	108±30	145±39	--	87±18	78±14
	4/26/76	5/18/76		7/21/76	8/21/76
Plot 6-0	70±30	54±23	--	51±20	95±49
Plot 6-F	61±13	61±12	--	81±13	96±22
Plot 6-C	200±73	195±57	--	262±120	404±89
Plot 6 (combined)	110±28	103±23	--	132±42	198±40

[1] Quadrat size for Plots 1, 2, 5, and 6 equals 0.25 m^2; Plots 3 and 4 equal 0.1 m^2.

n = 15 quadrats; combined n = 45 quadrats.

Differences in litter and prostrate dead among the sampling locations at Plots 5 and 6 show relationships similar to those for current live biomass (Table 3-3-15). At Plot 6 all of the observed significant differences involved the livestock plot. In May and August the litter and prostrate dead was significantly greater in the livestock plot than in either the open or deer-fenced plots. No significant differences were noted between the open and deer-fenced plots. At Plot 5 the relationship among the three treatments is different, and the livestock plot appears to have a less well-developed herb layer than either the deer-fenced or open plots. In May both the open and deer-fenced plots had a greater amount of litter and prostrate dead than occurred in the livestock plot, and in August the deer-fenced plot litter and prostrate dead was greater than that in the livestock plot.

3.3.5.5.1.3 Upland Sagebrush

The herb layer in the upland sagebrush community is more homogeneous than the herb layers in other communities. Western wheatgrass is one of the most abundant species and because of its rhizomatous growth form, the spatial variation of herb standing crop is lower in this community compared with others. Peak standing crop was reached in July when current live standing crop estimates equalled 254±21 kg/ha (Table 3-3-13). This was the highest value reached in any of the study plots during 1976. In both July and August the current live fraction was significantly greater in the deer-fenced and livestock-fenced plots than it was in the open plot, suggesting that at this location the cumulative treatment effects are beginning to be seen.

The standing dead biomass at Plot 3 was greater in the deer-fenced plot than it was in the open plot at each of the sampling dates, however, the difference was significant only in April (Table 3-3-14).

A buildup of litter and prostrate dead biomass can be seen at Plot 3 (Table 3-3-15). The amount of this biomass component was significantly greater in the deer-fenced plot than it was in the open plot at all sampling dates. Also, in May, July, and August the litter and prostrate dead was significantly greater in the livestock plot compared with the open plot. These data seem to reflect the grazing use which this site receives. All of the three treatments are subject to mechanical loss by wind, and decomposition rates and microbial activity are likely to be the same. (Some differences may eventually develop in microbial activity as a result of more plant material being available for decomposition.) Use of the site by livestock late in summer and in early spring removes a portion of the standing dead and current year's production, thus reducing the amount of biomass which passes on to the decomposers. Since the livestock plot is fenced with barbed wire when the cattle are on the Tract no standing dead or current year's production is removed from that plot either. After the cattle leave the Tract the barbed wire fence is removed and the area is available for use by deer. By this time of year the deer diet is composed primarily of woody shoots rather than grasses and forbs such that little herbaceous biomass is removed from the plot. Snow covers the plot and leaves the herb layer mostly inaccessible. In spring the site is again fenced before the cattle move into the area, thus allowing the litter and prostrate dead to accumulate since the standing dead falls and becomes part of this biomass component.

3.3.5.5.1.4 Bottomland Sagebrush

The herb layer in the bottomland sagebrush community is different from that in other communities on the Tract in that it is dominated by annual species rather than perennials. Cheatgrass is the dominant species and with the exception of a few perennial grasses provides most of the aboveground herbaceous production. Maximum standing crop in June was only 113±20 kg/ha (Table 3-3-13), thus making the bottomland sagebrush communities some of the least productive areas on the Tract in terms of herbaceous production. The only significant differences in current live standing crop at Plot 4 occurred in May between the livestock plot and both the open and deer-fenced plots with the livestock plot containing the larger biomass. The livestock plot is located slightly up-valley from the other two plots and includes a greater amount of perennial grasses than the other sampling areas. This difference may be sufficient to cause the disparity in standing crop estimates. The fences at this site probably cause minimal microclimatic changes, since the vegetation has a more continuous canopy and the individual plants are large relative to the height of the fence.

The differences between the open and deer-fenced plots and the livestock plot can also be seen in the standing dead and litter and prostrate dead biomass components (Tables 3-3-14 and 3-3-15). In May and August the standing dead was significantly higher in the livestock plot than that in the other two plots, and in August the litter and prostrate dead was greater in the livestock plot than in the deer-fenced plot. The only other significant difference was in litter and prostrate dead between the open and deer-fenced plot in August. The litter and prostrate dead was greater in the open plot, suggesting the limited effect which the fences are having in this vegetation type.

3.3.5.5.1.5 Differences among Vegetation Types

Differences in the maximum herbaceous standing crop among vegetation types were tested using a t-test comparing the combined current live data from a site during the month of peak standing crop.

The production in the upland sagebrush was significantly greater than that in pinyon-juniper woodlands and in the bottomland sagebrush community, but no significant difference existed between the upland sagebrush and chained rangelands. Differences between the chained rangelands and woodlands were significant when comparing Plots 1 and 2 with Plot 5, but not significant when compared with Plot 6. This is primarily a result of the livestock plot at 6 which increases the average standing crop at that location. Differences between the chained rangelands and bottomland sagebrush were not significant when tested at the 5 percent level of probability but were significant at the 10 percent level. Herbaceous standing crop differences between the woodlands and bottomland sagebrush community were not significant. Based on these comparisons, it appears that the upland sagebrush communities are the most productive (in terms of herb production) followed by the chained rangelands, pinyon-juniper woodlands, and finally, bottomland sagebrush.

The comparisons also give insight into the changes brought on by chaining. The data suggest that chaining has brought about a significant increase in herb production such that currently the production in the chained areas is comparable to that in the upland sagebrush communities. Depending on individual site characteristics, productivity in the chained areas and upland sagebrush communities is greater than in the woodlands.

3.3.5.5.1.6 Evaluation of Fencing Effects

In theory the three plot arrangement at each of the intensive study plots is designed to estimate the amount of biomass produced under three different treatments. The open plots are subject to grazing by domestic livestock and mule deer as well as insects and rodents. The deer-fenced plots exclude all large herbivores but still allow grazing and consumption by smaller plant eaters. The livestock-fenced plot (enclosed by barbed wire) is seasonally strung and taken down so that the areas are available to deer during the winter months when the cattle are kept in the bottomland meadows along Piceance and Willow Creeks. Several kinds of vegetation responses may be anticipated from these treatments. The presence of deer fences produces a situation unlike anything else in the area since in this portion of the Piceance Basin mule deer are abundant and utilize nearly all of the available habitat. Additionally, the simple presence of the fences can alter local mircoclimatic factors such as wind and to some extent solar radiation. Snowdrifts tend to accumulate in the lee of the fences and shadows cast by the wire can reduce sunlight intensities sufficiently to somewhat reduce plant-water stresses near the fences. In the fenced plots a buildup of litter and prostrate dead may be expected since the current live biomass is not being removed. This buildup of mulch also influences the microclimate in the ground layer such that evaporative losses may be reduced or possibly precipitation penetration may be affected. These are important factors which can influence amounts of primary production. The open plots provide an estimate of production exclusive of fencing influences but include herbivory. Theoretically, by comparing the biomass in the open plots with that in either the deer-fenced plot or livestock plot an estimate of the amount of large herbivore consumption would be obtainable. This approach could work reasonably well in a region with high herbivore utilization where differences in open and fenced plots would be obvious. On Tract C-b this is not really the case. The current grazing use patterns are such that by the time of maximum plant standing crop in late June and July the mule deer and cattle have moved to elevations above the Tract. Cattle first appear on the Tract in mid-to-late April, at which time new herbaceous standing crop is low. At this time it is likely that most of what the livestock consume consists of the standing dead fraction remaining in the herb layer from the previous years growth. This may be responsible for the significant differences noted between the open and deer-fenced plots in the upland sagebrush, which provides some of the better grazing areas on the Tract. Since the new current live is short and g/m^2 values are low, it is very difficult to measure any differences between open and fenced plots early in the growing season. Additionally, since the Tract area is large and the study plots are small relative to the entire area, the cattle do not spend much time in the vicinities of the plots. Evidence of cattle concentration (excessive trampling or large concentrations of cow dung) around the fences have not been observed and it appears that the study plots are not used to any greater extent than other Tract areas. By early to mid-June most of the cattle have moved away from the Tract to the summer rangelands at elevations above the Tract such that by the time peak current live standing crop is reached in late June and early July observable differences in the current live fraction are not readily apparent between the open and fenced plots. (The influences of fencing the plots can be seen in the upland sagebrush site primarily as a result of an increase in standing dead and litter and prostrate dead. Differences in the current live are difficult to assess visually at this plot.) Also, the lack of grazing during these months can be noted in that the grasses clipped as part of the sampling show limited evidence of having been partially eaten. The cattle do not return to the Tract until mid-to-late September, at which time some of the current year's growth is likely consumed. By this time most of the herbaceous plants are dried and senescent so that the cattle are actually removing part of the standing dead fraction. This may also influence the springtime differences in the standing dead between open and fenced plots. The period of late summer and early fall use on the Tract is limited, and the cattle are soon confined to the streamside meadows.

A similar situation exists with the mule deer. Seasonal movements result in the deer occurring at elevations higher than the Tract in the summer. In the fall and spring a certain amount of grazing by the deer can be noted. During normal winters much of the area is snow covered. Mule deer, even though they are on the Tract in winter, feed primarily on twigs of woody plants rather than on the herbaceous vegetation when it is available.

Under the conditions of the plot design and the use patterns of the large herbivores it is not surprising that few differences in the current live biomass exist during the growing season. At some sites (Plot 2) the standing crop is greater in the open plot than in the deer-fenced plot in both May and July. The upland sagebrush plot is the only studied location on the Tract where significant differences do occur at peak season. In both July and August the differences between the open and deer-fenced plots were significant. This may, however, be a function of the presence of the fence for two years rather than being a direct measure of herbivore consumption. Since the fenced plot has been protected there has been a greater opportunity for vegetative propagation (rhizomes) by western wheatgrass which is the most prevalent herb species at the site. This is also suggested by the fact that in 1975 the differences between the fenced and open plots were not significant, and since the grazing patterns were the same in both years the cumulative effect of grazing protection may be responsible for the differences. This is of interest since it suggests that removal of grazing at least initially would tend to increase herbaceous production. The microclimatic effects of wind alteration and shading are probably not a major influence on the data since all clip samples were made from areas at least 5 meters from the fences. Of greater significance would be the effect of increased mulch (litter and prostrate dead) which may be influencing plant-soil water relations.

Peak standing crop differences at other study locations in chained rangelands, woodlands, and bottomland sagebrush communities do not follow consistent patterns or relationships which may be related to anticipated fencing effects. For example, the standing crop may be significantly greater in open plots than in fenced plots at peak season (Plot 2). These differences may be related to the greater heterogeneity in the herb layer in these communities and thus greater variability in the standing crop data. The kinds of events which appear to be taking place in the upland sagebrush communities may be occurring in the other communities; however, they are more difficult to detect.

3.3.5.5.1.7 Herb Production Differences Between 1975 and 1976

One of the most interesting features of the herb production study has been the difference in maximum herb standing crop between the two baseline growing seasons (Tables 3-3-16, 3-3-17, and 3-3-18). Values for maximum standing crop were substantially higher at all study sites during 1975. Based on a t-test comparison of means, the differences at Plots 1, 3, 4, and 6 were significant at the 5 percent level of probability, and at a 10 percent probability level the differences were significant at all study sites.

The differences between years appear to be related to temperature and precipitation differences during the early growing season. The data from the micrometeorological stations suggest that 1975 was cooler and more moist than 1976, and thus provided conditions more conducive to plant growth. Additionally, in 1976 there was severe frost in early June which killed most of the new leaves on shrub species like oak, and also affected the developing inflorescences and leaf tips in the grasses and forbs. Temperatures were as low as -6°C at the micrometeorological stations.

Table 3-3-16 CURRENT LIVE STANDING CROP AT EACH OF THE INTENSIVE STUDY PLOTS DURING 1975[1]

	$\bar{X}$ ± S.E. (kgm/ha)			
	5/21/75	6/27/75	7/23/75	8/20/75
Plot 1-0	90± 26	375± 67	253± 54	228± 51
Plot 1-F	142± 50	375± 89	1006±521	406±190
Plot 1-C	185± 48	306± 96	561±109	225±147
Plot 1 (Combined)	139± 25	352± 48	607±181	286± 81
	5/20/75	6/26/75	7/22/75	8/19/75
Plot 2-0	94± 18	310± 68	740±378	361±108
Plot 2-F	88± 34	223± 81	316± 44	203±120
Plot 2-C	244± 68	415± 78	411±103	200± 69
Plot 2 (Combined)	142± 29	316± 45	421±135	255± 58
	5/21/75	6/27/75	7/23/75	8/20/75
Plot 3-0	300± 44	323± 43	555± 89	293± 43
Plot 3-F	293± 35	532± 56	542± 73	508±113
Plot 3-C	306± 29	705±106	580± 62	395± 66
Plot 3 (Combined)	300± 20	520± 50	534± 42	388± 44
	5/20/75	6/26/75	7/22/75	8/19/75
Plot 4-0	106± 44	337± 75	208± 79	212± 50
Plot 4-F	48± 13	251± 48	99± 39	219±107
Plot 4-C	82± 11	348± 71	456±173	146± 51
Plot 4 (Combined)	79± 16	312± 37	254± 68	135± 27
	5/22/75	6/28/75	7/24/75	8/21/75
Plot 5-0	57± 20	349± 84	175± 60	197±122
Plot 5-F	122± 45	94± 44	407±257	87± 43
Plot 5-C	36± 16	132± 61	109± 34	151± 89
Plot 5 (Combined)	72± 18	192± 42	232± 90	143± 51
	5/22/75	6/28/75	7/24/75	8/21/75
Plot 6-0	105± 46	107± 16	179± 44	132± 29
Plot 6-F	96± 20	156± 39	136± 30	271± 57
Plot 6-C	159± 39	475± 97	387± 88	505±135
Plot 6 (Combined)	120± 21	246± 46	234± 39	303± 56

[1] n = 10 0.1 m^2 quadrats; combined n = 30 quadrats.

Table 3-3-17 STANDING DEAD BIOMASS AT EACH OF THE INTENSIVE STUDY PLOTS DURING 1975[1]

	$\bar{X}$ ± S.E. (kgm/ha)			
	5/21/75	6/27/75	7/23/75	8/20/75
Plot 1-0	40± 17	73± 26	123± 34	125± 33
Plot 1-F	259±130	132± 46	276±155	307±100
Plot 1-C	145±107	38± 17	106± 40	232± 99
Plot 1 (Combined)	148± 57	81± 19	168± 54	222± 48
	5/20/75	6/26/65	7/22/75	8/19/75
Plot 2-0	60± 45	23± 18	84± 23	372± 96
Plot 2-F	36± 21	26± 10	185± 53	250±111
Plot 2-C	23± 13	31± 13	145± 48	230± 74
Plot 2 (Combined)	40± 17	27± 8	138± 25	284± 54
	5/21/75	6/27/75	7/23/75	8/20/75
Plot 3-0	81± 18	45± 14	56± 28	106± 27
Plot 3-F	138± 23	53± 13	102± 21	218± 40
Plot 3-C	28± 9	79± 24	111± 35	198± 45
Plot 3 (Combined)	80± 13	59± 10	90± 16	174± 23
	5/20/75	6/26/75	7/22/75	8/19/75
Plot 4-0	12± 2	27± 9	96± 20	143± 28
Plot 4-F	27± 15	45± 25	105± 11	97± 23
Plot 4-C	19± 5	64± 21	126± 21	164± 22
Plot 4 (Combined)	19± 5	45± 11	110± 10	135± 14
	5/22/75	6/28/75	7/24/75	8/21/75
Plot 5-0	36± 22	83± 35	83± 26	732±489
Plot 5-F	210± 75	51± 25	61± 26	61± 36
Plot 5-C	26± 14	50± 34	31± 12	135± 62
Plot 5 (Combined)	91± 30	61± 18	58± 13	308±168
	5/22/75	6/28/75	7/24/75	8/21/75
Plot 6-0	82± 35	24± 4	50± 16	48± 14
Plot 6-F	80± 15	64± 17	24± 6	57± 20
Plot 6-C	77± 30	40± 14	81± 22	244± 95
Plot 6 (Combined)	80± 27	43± 8	52± 10	116± 36

[1] n = 10 0.1 m^2 quadrats; combined n = 30 quadrats.

Table 3-3-18 LITTER AND PROSTRATE DEAD BIOMASS AT EACH OF THE INTENSIVE STUDY PLOTS DURING 1975[1]

	$\bar{X}$ ± S.E.(kgm/ha)			
	5/21/75	6/27/75	7/23/75	8/20/75
Plot 1-0	60± 15	91± 22	105± 19	154± 44
Plot 1-F	238±101	126± 36	172± 57	165± 40
Plot 1-C	136± 68	59± 18	103± 29	73± 25
Plot 1 (Combined)	145± 42	91± 15	127± 22	131± 22
	5/20/75	6/26/75	7/22/75	8/19/75
Plot 2-0	145± 42	127± 58	107± 46	238± 55
Plot 2-F	106± 34	71± 15	54± 16	86± 31
Plot 2-C	145± 29	104± 33	119± 23	210± 74
Plot 2 (Combined)	132± 20	101± 23	93± 18	178± 33
	5/21/75	6/27/75	7/23/75	8/20/75
Plot 3-0	218± 27	91± 13	113± 16	102± 15
Plot 3-F	102± 14	91± 14	93± 7	132± 17
Plot 3-C	72± 11	88± 9	155± 37	156± 15
Plot 3 (Combined)	130± 16	90± 7	120± 14	130± 10
	5/20/75	6/26/75	7/22/75	8/19/75
Plot 4-0	125± 37	67± 20	72± 15	101± 28
Plot 4-F	94± 17	42± 6	44± 8	51± 12
Plot 4-C	135± 26	88± 23	125± 29	117± 24
Plot 4 (Combined)	117± 16	66± 11	79± 12	90± 14
	5/22/75	6/28/75	7/24/75	8/21/75
Plot 5-0	75± 35	91± 30	157± 95	157± 47
Plot 5-F	90± 31	36± 17	434±347	31± 13
Plot 5-C	54± 24	63± 21	36± 20	149± 64
Plot 5 (Combined)	73± 17	63± 14	209±120	112± 28
	5/22/75	6/28/75	7/24/75	8/21/75
Plot 6-0	64± 17	70± 19	111± 20	86± 43
Plot 6-F	78± 27	68± 14	74± 15	51± 16
Plot 6-C	244±119	131± 52	118± 36	226±105
Plot 6 (Combined)	129± 42	90± 19	101±144	121± 39

[1] n = 10 0.1 m^2 quadrats; combined n = 30 quadrats.

The combination of the warm, dry spring and late frost was most likely sufficient to cause the yearly differences in herb production.

3.3.5.5.2 Shrub Production

Shrub production estimates have been developed on the basis of observations made on individual plants. Estimates of standing crop were prepared by multiplying density estimates for shrub species at each of the intensive study sites, times derived weight per plant values. Standing crop estimates were obtained in April and September in both 1975 and 1976 (Tables 3-3-19, 3-3-20, and 3-3-21). Differences between the beginning and end of the growing season were used as estimates of production (Table 3-3-22). The obtained values provide a general estimate of production; because of the high variation within the samples these values are not amenable to rigorous statistical testing. The values are sufficient to allow general comparisons among sites, between years, and also for comparison with other major vegetation types.

Because the estimates of current year's growth for mountain mahogany and bitterbrush were collected in a somewhat different manner, it has been possible to statistically evaluate growth differences for these species in pinyon-juniper woodlands and chained rangelands.

3.3.5.5.2.1 Bottomland Sagebrush Communities

In terms of shrub production the bottomland sagebrush communities are the most productive communities on the Tract. Mean shrub production was 6929 kg/ha/yr for Plot 4 for the 1976 growing season. This was nearly 17 times greater than the production for the upland sagebrush community which was the second most productive site. The high production values for this community type relate to the high density values for big sagebrush which accounts for more than 99 percent of the total shrub production. In 1975 the bottomland sagebrush site was also the most productive; however, the 1975 estimate was 1.8 times greater than that for 1976. In all vegetation types this relationship has been observed, and at some sites the differences between years are even more dramatic.

3.3.5.5.2.2 Upland Sagebrush Communities

Shrub production in the upland sagebrush community (Plot 3) averaged 415 kg/ha/yr during the 1976 growing season. Most of the production (97 percent) can be attributed to big sagebrush which is the dominant species on the site. Production estimates for 1975 were 2.4 times greater than those obtained for 1976. The differences between upland and bottomland sites relate both to differences in sagebrush density which is greater in the bottomland communities and

Table 3-3-19 SHRUB STANDING CROP ESTIMATES FOR MAJOR SHRUB SPECIES IN EACH OF THE INTENSIVE STUDY PLOTS FOR 1975

SPECIES \ PLOT	$\overline{X}$ ± S.E.(kgm/ha)					
	1	2	3	4	5	6
Amelanchier spp.						
April 1975	23± 6	76± 22	25± 7	-	63± 18	73± 21
September 1975	89± 39	55± 19	32± 12	-	78± 31	91± 36
Artemisia tridentata						
April 1975	1672± 619	251± 62	1360± 257	9172±2754	36± 7	281± 53
September 1975	2667± 587	450± 170	2332± 604	21745±6937	62± 16	482± 123
Ceratoides lanata						
April 1975	-	-	-	36± 5	-	-
September 1975	-	-	-	24± 5	-	-
Cercocarpus montanus						
April 1975	95± 25	62± 18	-	-	73± 20	-
September 1975	252± 82	152± 56	-	-	181± 64	-
Chrysothamnus nauseosus						
April 1975	163± 31	405± 77	15± 3	41± 8	6± 1	61± 12
September 1975	197± 55	490 ± 138	18± 5	49± 14	7± 2	73± 21
Juniperus osteosperma						
April 1975	33± 4	118± 15	5± 1	-	11± 1	29± 4
September 1975	55± 10	198± 35	8± 1	-	19± 3	49± 9
Pinus edulis						
April 1975	63± 9	97± 14	17± 2	1± 0.1	55± 8	28± 4
September 1975	101± 22	155± 33	27± 6	4± 1	87± 19	44± 10
Purshia tridentata						
April 1975	177± 31	74± 17	-	-	24± 5	2± 0.3
September 1975	488± 91	446± 75	-	-	112± 19	7± 1
Total						
April 1975	2226± 725	1083± 225	1422± 270	9249±2767	268± 60	474± 94
September 1975	3849± 886	1946± 526	2417± 628	21822±6957	546± 154	746± 200

Table 3-3-20 APRIL AND SEPTEMBER 1976 STANDING CROP ESTIMATES FOR MAJOR SHRUB SPECIES ($S_{\bar{y}}$ = STANDARD ERROR OF THE MEAN)

	No. of Observations	Mean Stem Weight $\pm S_{\bar{y}}$ (g)	Mean No. of Stems per Plant	Mean Weight (g) per Plant $\pm S_{\bar{y}}$
Purshia tridentata				
April 1976	20	61.4±14.5	5.75	353. ± 83.
September 1976	20	91.6±18.7		527. ± 108.
Cercocarpus montanus				
April 1976	20	88.2±24.5	8.62	760. ± 211.
September 1976	20	99.6±22.0		859. ± 190.
Amelanchier spp.				
April 1976	20	118.8±25.2	9.08	1079. ± 229.
September 1976	20	128.2±36.8		1170. ± 334.
Artemisia tridentata				
Upland Sagebrush				
April 1976	20	130.8±24.0	2.23	292. ± 54.
September 1976	10	156.8±48.3		350. ± 108.
Bottomland Sagebrush				
April 1976	20	101.3±21.1	3.43	347. ± 72.
September 1976	10	178.8±39.8		613. ± 137.
Chained Rangeland				
April 1976	20	115.1±26.2	5.52	635. ± 145.
September 1976	10	123.4±24.3		681. ± 134.
Pinus edulis				
April 1976	20	159.2±32.8	1.05	167. ± 34.
September 1976	20	188.8±32.2		198. ± 34.
Juniperus osteosperma				
April 1976	20	175.4±22.8	1.45	254. ± 33.
September 1976	20	131.6±20.6		191. ± 30.
Chrysothamnus nauseosus				
April 1976	20	64.2±11.3	7.60	488. ± 86.
September 1976	20	106.6±22.0		785. ± 167.
Ceratoides lanata				
April 1976	30	--	--	22.4± 3.4
September 1976	30	--		22.0± 4.0

Table 3-3-21 SHRUB STANDING CROP ESTIMATES FOR MAJOR SHRUB SPECIES IN EACH OF THE INTENSIVE STUDY PLOTS FOR 1976

SPECIES \ PLOT	1	2	3	4	5	6
	$\bar{X}$ ± S.E. (kgm/ha)					
Amelanchier spp						
April 1976	111± 24	73± 16	41± 9	-	101± 22	118± 25
September 1976	121± 34	80± 23	44± 13	-	110± 31	128± 36
Artemisia tridentata						
April 1976	1541± 352	214± 49	2026± 375	9015±1871	54± 10	419± 77
September 1976	1653± 325	229± 45	2429± 749	15926±3559	65± 20	502± 155
Ceratoides lanata						
April 1976	-	-	-	34± 5	-	-
September 1976	-	-	-	33± 6	-	-
Cercocarpus montanus						
April 1976	211± 59	49± 14	-	-	85± 24	-
September 1976	239± 53	56± 12	-	-	96± 21	-
Chrysothamnus nauseosus						
April 1976	116± 20	287± 51	11± 2	29± 5	4± 1	43± 8
September 1976	186± 40	462± 98	17± 4	46± 10	7± 2	69± 15
Juniperus osteosperma						
April 1976	25± 3	90± 12	4± 1	-	9± 1	22± 3
September 1976	19± 3	67± 11	3± 1	-	6± 1	17± 3
Pinus edulis						
April 1976	46± 9	70± 14	12± 3	-	40± 8	20± 4
September 1976	54± 9	84± 14	15± 3	-	47± 8	24± 4
Purshia tridentata						
April 1976	288± 68	88± 21	-	1± 0.2	33± 8	2± 0.5
September 1976	430± 88	132± 27	-	2± 0.3	50± 10	3± 1
Total						
April 1976	2338± 535	871± 177	2094± 390	9079±1881	326± 74	624± 117
September 1976	2702± 552	1110± 230	2508± 770	16007±3575	381± 93	743± 214

Table 3-3-22 PRODUCTIVITY FOR MAJOR SHRUB SPECIES AT EACH OF THE INTENSIVE STUDY PLOTS FOR 1975 AND 1976

SPECIES \ PLOT	$\overline{X}$ ± S.E. (kgm/ha)					
	1	2	3	4	5	6
Amelanchier spp.						
1975	66	*	7	-	15	18
1976	10	7	3	-	9	10
Artemisia tridentata						
1975	995	199	972	12574	26	201
1976	112	15	403	6911	11	83
Ceratoides lanata						
1975	-	-	-	*	-	-
1976	-	-	-	*	-	-
Cercocarpus montanus						
1975	157	90	-	-	108	-
1976	28	7	-	-	11	-
Chrysothamnus nauseosus						
1975	34	85	3	8	1	12
1976	70	175	6	17	3	26
Juniperus osteosperma						
1975	22	80	3	-	8	20
1976	*	*	*	-	*	*
Pinus edulis						
1975	38	58	10	-	32	16
1976	8	14	3	-	7	4
Purshia tridentata						
1975	311	372	-	3	88	5
1976	142	44	-	1	17	1
Total						
1975	1623	884	995	12585	278	272
1976	370	262	415	6929	58	124

* No measured increase.

also to the magnitude of yearly increases in individual plants which are also greater in the bottomland communities.

3.3.5.5.2.3 Chained Rangelands

Shrub production in the chained rangelands was slightly lower than that in the upland sagebrush communities and averaged 370 kg/ha/yr at Plot 1 and 262 kg/ha/yr at Plot 2. Big sagebrush is also an important component in these communities; however, other species like bitterbrush, mountain mahogany, and rubber rabbitbrush account for an important part of the shrub production. At Plot 1 the 1975 production estimate was 4.4 times, and at Plot 2 the 1975 estimate was 3.4 times greater than 1976. During both years production estimates were greater at Plot 1 owing primarily to the higher density of big sagebrush at this site.

3.3.5.5.2.4 Pinyon-Juniper Woodlands

The pinyon-juniper woodland sites are the least productive communities on the Tract in terms of shrub production. Competition with the trees limits the extent to which the shrub layer develops on most sites. Shrub production was only 58 kg/ha/yr at Plot 5 and 124 kg/ha/yr at Plot 6. These values, which are lower than those for the chained rangelands, relate primarily to the lower shrub densities which characterize the woodlands. Also, the data from the current year's growth study of mountain mahogany and bitterbrush suggest that individual plants produce more in the chained rangelands than do the plants in the woodlands. Estimates of production for 1975 were 4.8 times greater at Plot 5 and 2.2 times greater at Plot 6 than the 1976 estimates at these sites.

3.3.5.5.2.5 Comparison Between 1975 and 1976

The observed differences in shrub production between the baseline years strongly reflect the lower estimates obtained for herb production during 1976.

All sites showed substantial reductions in production estimates with the differences being greatest in the chained rangeland and pinyon-juniper communities. The observed differences may well relate to precipitation and temperature differences between the two years. While total precipitation during each of the two years was approximately the same, the distribution pattern was much different (see also Section 1, Microenvironmental Studies). Spring rains continued through May and well into June during 1975, while in 1976 most of the rains came in March and April. The early 1975 growing season was cooler, while in 1976 the May and June temperatures were quite warm. The combination of the warm, dry conditions in 1976 apparently was not as conducive to plant growth as were the cool, relatively moist conditions in 1975. Also in 1976 there was a very late killing frost which occurred in early June, just at the time when many of the new shrub shoots were vulnerable to low temperatures (on June 13, 1976 the temperature dropped to -6°C for a period of less than 12 hours). Gambel's oak was apparently the most hard hit, but other species like serviceberry, snowberry, and mountain mahogany also had shoots partially or completely frozen. Nearly all of the new leaves on the oaks were killed, and it wasn't until well into the summer that the shoots and leaves produced after the freeze covered the individual oak shrubs. Bitterbrush seemed to be the least affected by the freeze. The warm, dry spring and early summer in conjunction with the late killing frost were most likely responsible for the wide disparity in shrub production estimates for the two years. It is also conceivable that the 1975 production values may represent estimates derived under some of the best environmental conditions which could possibly occur regionally. If this is the case, then the two-year baseline sampling period provides estimates of production under some of the best as well as some of the most adverse environmental conditions.

3.3.5.5.2.6 Current Year's Growth Studies

The study of current year's growth for bitterbrush and mountain mahogany has provided an estimate of growth differences for these species in the chained rangelands and pinyon-juniper woodlands. Observations on both species were made on the number of stems per plant, number of new shoots per stem, lengths of new shoots, weight of new shoots, and weight of leaves on new shoots (for mountain mahogany only) at six sites; three each in chained rangelands and pinyon-juniper woodlands (Table 3-3-23).

For mountain mahogany there were no significant differences in leaf weight per new shoot or in twig weight per new shoot between the woodlands and chained rangelands (based on a t-test at 0.05 level of probability). There was a difference, however, in the number of new shoots per stem with the estimates for plants in the chained rangelands being significantly greater than those in the woodlands. There was no significant difference in the number of stems per plant. The weight data per shoot can be extrapolated to estimates per hectare by multiplying the mean weight per shoot, times the mean number of shoots per plant, times the mean number of stems per plant, times the mean density for a species in each of the community types. (Mean density for mountain mahogany was 172 plants per hectare in the woodlands and 279 plants per hectare in the chained rangelands.) The derived estimates for current growth for mountain mahogany were 16.1 kg/ha (12.8 kg/ha new shoots plus 3.3 kg/ha leaves) in the pinyon-juniper woodlands and 28.4 kg/ha (23.6 kg/ha new shoots plus 4.8 kg/ha leaves). If the same average density values are used with the weight increase estimates derived from the other shrub production estimates, the estimates of total

Table 3-3-23 SUMMARY OF SHOOT AND TWIG WEIGHT, LENGTH, AND NUMBER ESTIMATES FOR MOUNTAIN MAHOGANY AND ANTELOPE BITTERBRUSH (1976) IN PINYON-JUNIPER WOODLANDS AND CHAINED RANGELANDS ($S_{\bar{y}}$ = STANDARD ERROR OF THE MEAN)

	No. of Observations	Mean ± $S_{\bar{y}}$
Pinyon-Juniper Woodland		
Cercocarpus montanus		
New Shoot Lengths (mm)	146	69.52 ± 3.47
New Shoot Twig Weights (g)	146	0.142 ± 0.011
New Shoot Leaf Weights (g)	146	0.097 ± 0.005
No. of shoots per stem	14	18.36 ± 3.82
No. of stems per plant	15	10.8 ± 1.6
Purshia tridentata		
New Shoot Lengths (mm)	150	143.85 ± 6.32
New Shoot Twig Weights (g)	150	0.170 ± 0.011
No. of shoots per stem	15	116.80 ± 16.49
No. of stems per plant	15	3.3 ± 0.4
Chained Rangelands		
Cercocarpus montanus		
New Shoot Lengths (mm)	151	83.78 ± 4.19
New Shoot Twig Weights (g)	151	0.166 ± 0.011
New Shoot Leaf Weights (g)	151	0.090 ± 0.004
No. of shoots per stem	15	42.47 ± 8.83
No. of stems per plant	15	12.0 ± 2.2
Purshia tridentata		
New Shoot Lengths (mm)	148	165.44 ± 6.99
New Shoot Twig Weights (g)	149	0.206 ± 0.014
No. of shoots per stem	15	263.07 ± 30.36
No. of stems per plant	15	4.3 ± 0.7

increase in weight are 17.0 kg/ha for woodlands and 27.6 kg/ha for chained rangelands. The data suggest that the total weight increase estimates may be low, since they also include increases from radial growth on existing stems. Radial growth is not included in the current year's growth estimates. The two data sets do complement one another and seem to be providing reasonable estimates for production by mountain mahogany.

The estimates for bitterbrush current year's growth show greater differences between the two vegetation types. Shoot lengths, shoot weights, and the number of shoots per stem were all significantly greater in the chained rangelands. (No leaf weight estimates were obtained, since many of the small leaves had fallen from the plants prior to sample collection.) Differences in the number of stems per plant were not significant. The magnitude of differences in weight and number of shoots per stem resulted in a substantial difference in the current year's growth estimate between the rangelands and woodlands. New shoot growth was estimated at 108 kg/ha/yr for rangelands and 32 kg/ha/yr for the woodlands. These production estimates are higher than those obtained for the intensive study sites in both the woodlands and rangelands. Since the sampling program for the current year's growth study included a larger sample and a more precisely defined parameter for estimation, the estimates probably more closely approximate the actual values than those from the other shrub production studies.

The higher values in the chained rangelands for bitterbrush and mountain mahogany suggest their relative importance in terms of browse production. While density values for mountain mahogany and bitterbrush may be highly variable from site to site within the chained rangelands, the actual amount of biomass per plant is greater than that in the woodlands.

It is not surprising that the removal of trees should have the effect of stimulating the growth of shrubs. Removal of the canopy opens the community and eliminates competition between the trees and shrubs providing the shrubs with a greater potential for obtaining water, nutrients, and solar radiation. In the chained areas the greatest amount of energy flow has been shifted away from the trees such that the shrub and herb layers now account for the principal routes of energy flow. In the woodlands the tree canopy has remained unaltered with the result being that the largest percentage of production is provided by the trees with lesser amounts of energy flowing through the other synusia. Chaining may be an efficient means for increasing forage and browse production, but its capacity for increasing total community production remains unknown, since no estimates for production by pinyon pine are available.

3.3.5.6 Decomposition and Litter Studies

3.3.5.6.1 Decomposition Studies

The decomposition packets were first placed in the field during November of 1974. Based on the assumption that decomposition rates were likely to be quite slow as a result of the semi-arid environment, the packets were left in the field during the 1975 growing season and also through the winter of 1975-1976. The first retrieval of samples did not occur until April of 1976 (17 months after their original placement). The second retrieval occurred in September 1976 (22 months after original placement). One of the most interesting aspects of the study is that at some locations, certain of the experimental materials decomposed at a more rapid rate than was initially anticipated (Tables 3-3-24 and 3-3-25).

Decomposition of serviceberry leaves has occurred at a relatively consistent rate at each of the sites (Table 3-3-26). On a monthly basis decomposition rates ranged from 2.45 to 3.22 percent per month after 17 months and 2.10 to 3.35 percent per month after 22 months for surface samples. The ranges for samples at a depth of 10 cm were slightly higher (2.61 - 4.25 after 17 months and 2.02 - 3.45 after 22 months). The similarity of the decomposition rates obtained from the two collection dates suggests that decomposition is progressing at a relatively constant rate for these samples rather than showing a rate decrease with an accordant increase in field time.

Mountain mahogany leaves have shown similar decomposition patterns. Surface rates ranged from 2.64 to 3.17 percent per month after 17 months and 2.81 to 3.18 percent per month after 22 months (Table 3-3-26). Subsurface rates after 17 months were approximately one percent per month higher than the surface rates (3.45 to 4.97). After 22 months the differences between surface and subsurface rates were approximately one-half of one percent (2.25 to 3.84).

Leaves of big sagebrush showed a different pattern of decomposition. Surface and subsurface rates were approximately the same after 17 months and after 22 months. The rates of decomposition showed a decrease with time. Rates based on the first collected samples were greater than those collected later, suggesting that for sagebrush leaves early decomposition rates are more rapid and that after much of the material has decomposed, the rates decrease. This pattern is likely to occur with other species, but to date the data do not reflect it.

The cellulose standards (Watman #50 filter paper) showed a very different decomposition pattern. Surface rates were very low, ranging from 0.06 to 1.45 percent per month after 17 months. The high value appears to be aberrant since after 22 months the surface rates ranged from 0.24 to 0.96 percent per month. It appears that a longer period of time is required for the cellulose standards on the ground surface to be infused with microbial organisms. The pattern for the subsurface samples was opposite that of the surface samples. The highest decomposition

Table 3-3-24 MEAN PERCENT DECOMPOSITION OF LEAF SAMPLES AND CELLULOSE STANDARDS AFTER 17 MONTHS OF TIME IN THE FIELD[1]

SPECIES \ PLOT	$\overline{X} \pm$ S.E. (kgm/ha) 1	2	3	4	5	6
Amelanchier spp. (leaves)						
Surface	54.8±1.4	47.9±3.0	--	--	41.7±2.1	47.0±3.4
10 cm Depth	53.3±6.0	72.2±6.8	--	--	50.1±4.5	44.4±2.5
Cercocarpus montanus (leaves)						
Surface	46.8±4.3	48.4±3.4	--	--	53.9±1.2	44.9±3.4
10 cm Depth	60.1±3.5	84.5±7.0	--	--	69.3±3.0	58.6±3.3
Artemisia tridentata (leaves)						
Surface	--	--	68.7±1.9	62.6±2.4	--	--
10 cm Depth	--	--	66.7±1.6	70.4±1.9	--	--
Cellulose Standards (Watman #50 filter paper)						
Surface	8.1±4.4	3.3±2.2	1.1±0.6	24.6±10.1	3.2±1.2	6.2±2.4
10 cm Depth	83.5±3.7	40.5±7.7	35.7±4.1	55.3±12.9	87.9±1.6	88.4±4.5

[1] n = 6 observations

Table 3-3-25 MEAN PERCENT DECOMPOSITION OF LEAF SAMPLES AND CELLULOSE STANDARDS AFTER 22 MONTHS OF TIME IN THE FIELD[1]

SPECIES \ PLOT	$\bar{X}$ ± S.E. (kgm/ha)					
	1	2	3	4	5	6
Amelanchier spp. (leaves)						
Surface	73.7±4.0	46.2±7.9	--	--	54.8±2.0	57.5±4.7
10 cm Depth	69.4±4.0	76.0±9.3	--	--	44.5±5.1	58.9±3.2
Cercocarpus montanus (leaves)						
Surface	65.4±7.6	69.9±5.4	--	--	61.8±3.1	67.6±2.9
10 cm Depth	74.5±3.4	84.5±7.1	--	--	49.4±5.9	70.4±4.0
Artemisia tridentata (leaves)						
Surface	--	--	80.2±5.1	75.9±2.2	--	--
10 cm Depth	--	--	67.9±1.4	74.7±2.3	--	--
Cellulose Standard (Watman #50 Filter Paper)						
Surface	16.9±6.0	21.2±5.3	10.4±2.4	16.4±3.7	5.2±1.9	12.6±1.7
10 cm Depth	84.8±6.3	74.7±8.2	42.4±3.8	91.7±4.6	93.7±3.4	99.4±0.6

[1] n = 6 observations

Table 3-3-26 DECOMPOSITION RATES FOR LEAF SAMPLES AND CELLULOSE STANDARDS AT EACH OF THE INTENSIVE STUDY PLOTS (VALUES ARE IN PERCENTS/MONTH)

	Plot Number (17 months*)						Plot Number (22 months**)					
	1	2	3	4	5	6	1	2	3	4	5	6
Amelanchier spp.												
Surface	3.22	2.82	-	-	2.45	2.76	3.35	2.10	-	-	2.49	2.61
10 cm	3.14	4.25	-	-	2.95	2.61	3.15	3.45	-	-	2.02	2.68
Cercocarpus montanus												
Surface	2.75	2.85	-	-	3.17	2.64	2.97	3.18	-	-	2.81	3.07
10 cm	3.54	4.97	-	-	4.08	3.45	3.39	3.84	-	-	2.25	3.20
Artemisia tridentata												
Surface	-	-	4.04	3.68	-	-	-	-	3.65	3.45	-	-
10 cm	-	-	3.92	4.14	-	-	-	-	3.09	3.40	-	-
Cellulose Standard												
Surface	0.48	0.19	0.06	1.45	0.19	0.36	0.77	0.96	0.47	0.75	0.24	0.57
10 cm	4.91	2.38	2.10	3.25	5.17	5.20	3.85	3.40	1.93	4.17	4.26	4.52

* 5.88 percent per month is maximum possible for 17 month interval.

** 4.55 percent per month is maximum possible for 22 month interval.

rates for any of the test materials were obtained from the cellulose standards at Plot 6 after 17 months and after 22 months. Values ranged from 2.10 to 5.20 percent per month after 17 months and 1.93 to 4.52 percent per month after 22 months. The high values closely approximate the maximum possible decomposition rates of 5.88 percent per month after 17 months and 4.55 percent per month after 22 months.

The design of the study allowed for evaluation of various factors influencing decomposition. Differences in placement (surface or 10 cm depth), time in field (17 months or 22 months), test materials (leaves or cellulose standard), and site differences (intensive study Plots 1 - 6) were all evaluated using t-tests. In each case only two data sets were compared to test whether mean decomposition rates were the same. The hypothesis that all means were the same was not tested. A two-tailed test at a 0.05 probability level was utilized.

3.3.5.6.1.1 Sample Depth Comparisons

A total of 32 comparisons between samples at the surface and samples at a 10 cm depth was made. Of these, 75 percent showed greater decomposition at the 10 cm depth with a total of 60 percent showing significant differences. Decomposition of mountain mahogany leaves was significantly greater at a 10 cm depth compared to the surface after 17 months at all test locations. After 22 months the differences were significant only at Plot 5 (pinyon-juniper woodland). Differences in serviceberry leaves were significant only at Plot 2 (chained rangeland) after both 17 months and 22 months. Decomposition of big sagebrush leaves was significantly greater at a 10 cm depth at Plot 4 (bottomland sagebrush) after 17 months, and after 22 months surface decomposition was significantly greater at Plot 3 (upland sagebrush). Decompositon of the cellulose standard was significantly greater at 10 cm than at the surface at all sites both after 17 months and 22 months.

For leaves, it appears that decomposition initially occurs at a more rapid rate for subsurface samples, but after longer time periods surface decomposition rates approximate subsurface values.

3.3.5.6.1.2 Time Comparisons

A total of 32 comparisons between samples collected after 17 months and 22 months was made. Eighty-four percent of the comparisons showed decomposition to have been greater after 22 months. Fifty-six percent of the comparisons were significantly different. All of the materials showed a similar pattern relative to greater lengths of time in the field. The tendency was for the samples to have lost more weight after 22 months than after 17 months.

3.3.5.6.1.3 Test Material Comparisons

A total of 56 comparisons was made among the various test materials. Seventy-five percent of the comparisons revealed significant differences in the amount of decomposition. In general, all leaf samples decomposed more rapidly than the cellulose standards at all locations on the surface. At the 10 cm depth, however, the tendency was reversed. Decomposition of mountain mahogany leaves was significantly greater than that for serviceberry leaves at Plots 2, 5, and 6, and serviceberry leaf decomposition was never significantly greater than mountain mahogany. In all comparisons involving mountain mahogany, this species showed significantly more rapid decomposition in 47 percent of the comparisons. Comparisons involving serviceberry showed that decomposition for this species was significantly greater only 28 percent of the time. The value for the cellulose standards in these comparisons was 30 percent. Comparisons involving big sagebrush showed that it was significantly greater than 75 percent of the time (this species was compared only with the cellulose standard).

In general, it appears that big sagebrush leaves decompose the most rapidly, followed by mountain mahogany leaves, serviceberry leaves, and then the cellulose standards. This could be a function of the size of the individual materials. Big sagebrush leaves were the smallest of the test materials and the discs of filter paper were the largest; mountain mahogany and serviceberry leaves were intermediate in size.

3.3.5.6.1.4 Site Comparisons

A total of 112 site-to-site comparisons was made. Of these, 45 percent of the differences were significant. The decomposition rates were significantly greater in chained rangeland sites in 31 percent of the comparisons involving this vegetation type. Pinyon-juniper woodland decomposition rates were significantly greater in 20 percent of the comparisons; bottomland sagebrush rates were greater in 17 percent; and upland sagebrush were greater in only 4 percent of the comparisons involving these types. Significant differences were noted in comparisons involving all of the vegetation types. No one community type stood out as having consistently higher or lower decomposition rates. However, the relatively high number of significant differences among the sites suggests that individual test locations on the ground can affect the estimates of decomposition. The important features appear to be individual placement of the packets rather than the community in which they are located. To the extent possible, an attempt was made to locate the packets in comparable situations within each of the vegetation types. Local variations in microfloral populations are most likely responsible for the measured differences among vegetation types.

3.3.5.6.2 Litter Fall Studies

The study of litter fall in the woodlands and bottomland sagebrush community has been limited in its scope. Seasonal collection of litter has provided a general estimate of the rate at which dead plant materials are added to the ground layer (Table 3-3-27). Most of the collected litter in the woodlands consisted of pinyon-pine needles and the scale-like leaves of the junipers. The litter fall is highly variable in its distribution on the ground owing primarily to the open canopy character of the woodlands. Litter tends to accumulate directly underneath the individual trees with only a sparse amount of litter falling on the areas away from the immediate tree canopies. The litter traps were randomly placed with some of the locations falling under the trees with others placed in the open. Mean litter fall at Plot 5 was 139±8 g/m^2 during the period of October 1974 to September 1975 and was 83±19 g/m^2 during the period from October 1975 to September 1976 (plus and minus values are equal to the standard error of the mean). Decomposition of these materials appears to occur quite slowly since large accumulations of litter can be seen under each of the trees.

In the bottomland sagebrush community the vegetation canopy is much more continuous, and litter fall is more homogeneous. The litter consists primarily of leaves of big sagebrush; however, a small amount of stem, twigs, and inflorescences also were present in the samples. Mean litter fall during the period of October 1974 to September 1975 was 124±22 g/m^2, and from September 1975 to September 1976 was 97±22 g/m^2. Decomposition of these materials occurs at an average rate of 3.56 percent per month based on data from the decomposition studies. This would be equivalent to a turnover rate of approximately 28 months for all leaf material to decompose. Even after this length of time a small amount of leaf tissue is likely to remain. Based on an average of 110 $g/m^2/yr$ of leaf litter production, average daily decomposition rates would be approximately 0.13 $g/m^2/day$. This estimate does not take into consideration that decomposition would be greater during the warmer months of the year.

Although no litter fall estimates are available for the chained rangelands, estimates of leaf production for mountain mahogany were obtained as part of the current year's growth study (Table 3-3-23). Estimates of leaf production were 3.3 kg/ha/yr for pinyon-juniper woodlands and 12.8 kg/ha/yr for chained rangelands. These estimates were based on samples collected just prior to leaf fall so that they closely approximate the amount of leaf tissue added to the litter. It is possible that some of the minerals and nutrients were translocated prior to fall; however, these would probably not greatly alter the kg/ha/yr estimates. For chained rangelands the average decomposition rate was 2.94 percent per month for mountain mahogany leaves. This is equivalent to a turnover rate of 34 months for complete decomposition of the leaves. Daily amounts of decomposition are very low (0.001 $g/m^2/day$) because of the limited amount of leaves produced. Calculations for

Table 3-3-27 ESTIMATES OF MEAN LEAF AND TWIG LITTER FALL RATES IN A BOTTOMLAND SAGEBRUSH COMMUNITY (PLOT 4) AND IN PINYON-JUNIPER WOODLANDS (PLOTS 5 AND 6)

Time Interval	PLOT 4		PLOT 5		PLOT 6	
	g/m^2	Kg/Ha	g/m^2	Kg/Ha	g/m^2	Kg/Ha
	$\bar{X}$ ± S.E. (kgm/ha)					
November 1974-September 1975	124±22	1239±219	139± 8	1390± 78	--	--
October 1975-September 1976	97±22	965±218	82±19	824±187	71±24	707±239

pinyon-juniper woodlands based on a mean decomposition rate of 2.29 percent per month and a turnover rate of 34 months provide an estimate of 0.0003 $g/m^2/day$ of decomposition for mountain mahogany leaves. This extremely low value relates to the low production of leaves in the woods.

3.3.5.7 Herb Phenology Studies

The herb phenology studies were conducted in order to obtain general information concerning the development of the major herbaceous species. Observations were made at the intensive study plots, and the species which were most prevalent at these locations were studied. Most of the species were perennial grasses and these can be treated as a group since their growth patterns were similar. There was a general tendency for a large percentage of the populations of perennial grasses to remain vegetative and produce only a few flowering heads (Appendix IV-B, Table B-3-37). This was true both in the chained rangelands and pinyon-juniper woodlands for Indian ricegrass, squirreltail grass, crested wheatgrass, and little ricegrass. Western wheatgrass in the upland sagebrush community (Plot 3) produced only a few inflorescences with more than 90 percent of the population remaining vegetative throughout the entire growing season. A second important feature of the perennial grasses is that by the time of the last observations in August only a small percentage of the populations had become senescent. It seems likely that the grasses would still be available for the cattle when they move through the Tract area in late summer and early fall.

The forbs which were observed (scarlet glove mallow and long-leaved phlox) did not produce any flowers on the plants which were studied. Other individuals within the study area did flower, but the percentage of the population which did was low enough that it was not encountered in the sample. It is possible that the warm, dry growing season conditions were responsible for limited flowering of the perennial grasses and the very limited flowering of the forbs.

The only annual species that was studied was cheatgrass. Data from the bottomland sagebrush community (Plot 4) demonstrate the effectiveness of this species in flowering and producing seed even in a year with poor moisture availability. In May no flowering heads were observed, but by mid-June 67 percent of the population was flowering and another 16 percent was either producing culms or inflorescence buds. By mid-July 76 percent of the population was becoming senescent. This species is certainly well equipped for handling the semi-arid conditions characterizing the Tract.

The data collected during this study suggest that herb phenology may be too variable a factor to be used in long-term monitoring. The information concerning low flowering percentages, however, will be useful for comparing with future observations, but not at a statistical testing level of accuracy.

3.3.5.8 Shrub Stem Growth Studies

The marked twig study was originally designed to provide data on the phenological development of the major shrub species. Program changes, however, resulted in a reduction of effort such that observations of marked twigs have been limited to the measurement of stem lengths at the beginning and end of the growing season. These measurements have given insight into the seasonal development of the major shrub species and provided estimates of growth differences in the major plant communities. Examination of data from fenced and open plots has provided insight into the effects of browsing and browse removal on the total growth of the marked shrubs.

In the following discussion the term "main twig" refers to the original twig which was randomly selected, measured, and marked in September of 1974. These same twigs were re-measured in June and September of 1975, and May and September of 1976. The term "lateral twig" or "laterals" refers to the growth and increase in length of lateral shoots which have developed on the originally marked twig. Three species were selected for inclusion in this study. Measurements have been made on serviceberry and mountain mahogany in the chained rangeland sites (Plots 1 and 2) and in the pinyon-juniper woodland sites (Plots 5 and 6 for serviceberry, and Plot 5 for mountain mahogany since it does not occur in Plot 6). Big sagebrush has been marked and re-measured in the upland sagebrush (Plot 3) and bottomland sagebrush (Plot 4) sites. Mean twig increases for all species and all sites are presented in Appendix IV-B, Tables B-3-38 and B-3-39.

3.3.5.8.1 Amelanchier spp.

Serviceberry is a common species in the region surrounding Tract C-b. At elevations above the Tract individual clumps of this species may be ten feet tall and more than ten feet in diameter; however, on the Tract individual serviceberry plants are usually smaller. Serviceberry occurs throughout the chained rangeland communities, and also to a lesser extent in the pinyon-juniper woodlands.

In the chained rangelands the competition between trees and shrubs has been eliminated as a result of chaining, thus providing a greater amount of sunlight, nutrients, and water for shrub growth than are available in the pinyon-juniper woodlands. Consequently, total stem growth (elongation of main twig plus growth of laterals) was 3.1 times greater in the fenced, chained rangeland plots than in the fenced pinyon-juniper plots. In the open plots, total stem growth was 4.6 times greater in the chained rangeland than in the woodland plots.

Total growth in the fenced, chained rangeland plots was an average of 1.4 times greater than that in the open plots, and was 2.1 times greater in the fenced pinyon-juniper plots than in the open woodland plots. The growth differences most likely occur as a result of browsing by large herbivores. The above values are based on comparison of measurements made in September 1974 and September 1975. During this time the shrubs in the fenced plots have been completely protected from large browsing animals while the shrubs in the open plots have been browsed and have had to adjust to the conditions brought on by removal of main twigs and terminal buds. While total growth of serviceberry was greater in the fenced plots, both in the chained rangelands and woodlands, it is of interest to note that lateral shoot growth was 1.6 times greater in the open, chained plots compared with the fenced plots, and was 1.3 times greater in the open woodland plots than in the fenced plots. Laterals readily developed in both the fenced and open plots. However, the removal of terminal buds as a result of browsing stimulated more lateral shoot growth in the open plots during the first season of field observations. The growth pattern of the main twigs caused the total growth in the fenced plots to be greater than that in the open plots. In the chained, fenced plots the average increase in main twig length (September 1974 to September 1975) was 48 percent of the 1974 length. During this same period, the main twig length on the marked shrubs in the open plots experienced an average decrease of 60 percent at Plot 1 and a 1.8 percent increase at Plot 2. The differences here result from removal of terminal buds. Once the terminal bud has been removed from a twig, all future growth associated with that twig must come from the development of a lateral bud. In the fenced plots the terminal buds are not removed allowing continual growth and elongation of the marked main twigs.

The same pattern can be seen in the data from the pinyon-juniper woodland plots. Main twigs in the fenced plots showed an average increase of 70.5 percent of the 1974 lengths, but only a 5.8 percent increase in the open plots.

After two years of protection from browsing some slightly different patterns have developed. Total increase in twig length, increase in laterals, and increase in main twigs were greater in the fenced plots in both the chained rangelands and pinyon-juniper woodlands (except for increase in main twigs at Plot 5).

3.3.5.8.2 Cercocarpus montanus

Mountain mahogany is also a relatively common species on the Tract and occurs mostly in the chained rangelands and to a lesser extent in the pinyon-juniper woodlands. While both mountain mahogany and serviceberry tend to occur in the same areas, some differences in stem elongation patterns and responses can be seen.

Total stem growth in the fenced, chained rangeland sites was 2.5 times greater than that in the pinyon-juniper fenced plot. In the open, chained plots the mean increase in length was 35.2 mm; however, in the woodland plot there was no net increase, but rather a mean decrease during the studied time interval. In the chained sites, total growth in Plot 1-F (fenced) was 81 times greater and in Plot 2-F, 2.6 times greater than in the open plots at these two sites. In the pinyon-juniper woodland plot, there was a mean net increase of 85.8 mm per twig in the fenced plot and a mean decrease of 21.5 mm per twig in the open plot.

Lateral shoot growth was 5.1 times greater in the fenced plot than in the open plot at chained Site 1, but was 1.8 times greater in the open plot at Plot 2. At the pinyon-juniper site, lateral shoot growth was 2.5 times greater in the fenced plot than in the open plot. The relationship between buds and lateral shoot development is also true for mountain mahogany, but this response appears to be overridden in the study plots most likely owing to the amount of browse damage which the main twigs incurred during the observation period. The average increase in main twig length during 1975 in the fenced, chained plots was 45 percent of the fall 1974 measurements. In the open plots at these same sites the main twigs showed an average decrease of 45 percent. In the woodland site the average increase in the fenced plot was 94 percent, but in the open plot there was an average decrease of 47 percent in the length of the main twig.

After two years, the increase in lateral shoots at Plot 1 was 1.6 times and the increase in main twigs was 3.1 times greater than that in the open plot. At Plot 2 lateral increases were 1.3 times greater in the open plot. In the pinyon-juniper woodland (Plot 5) total growth in the fenced plot was 7.3 times greater than that in the open plot.

3.3.5.8.3 Artemisia tridentata

Big sagebrush is one of the most abundant plants on Tract C-b. Data have been recorded in Plot 3 in an upland sagebrush community and in Plot 4, a bottomland sagebrush community.

Measurement of twig elongation for species like mountain mahogany and serviceberry is somewhat easier than for big sagebrush. Sagebrush appears to produce two different types of stems during the growing season. Stems which remain vegetative tend to show only limited elongation while those which eventually develop inflorescences tend to become much longer than the vegetative shoots.

Total stem growth in the fenced bottomland and upland plots was essentially the same; however, growth in the open bottomland plot was 4.7 times greater than in the open, upland plot. In the bottomland plots total stem increases were essentially the same in both the fenced and open plots. At the upland site total growth was 4.8 times greater in the fenced plot than in the open plot.

Lateral shoot growth was approximately the same in the fenced and open bottomland sagebrush plots. In the upland plots lateral growth was 2.8 times greater in the fenced plots. Increases in the main twig lengths in the bottomland plots were 39 percent and 26 percent in the fenced and open plots, respectively. These values represent increases in excess of the 1974 measurements. In the upland site the mean main twig increases were 28 percent in the fenced plot; however, there was a mean decrease of 34 percent in the open plot.

Little browsing occurs in the bottomland plots as is evidenced by the lack of differences between the fenced and open plots. At the upland site, however, there appears to be enough utilization of the sagebrush plants to result in measurable differences between the open and fenced plots.

3.4 Animals

The Final Baseline Report for animal studies on Tract C-b includes a summarization of all component programs conducted during the two-year baseline period. Component programs discussed include Big Game, Medium-sized Mammals, Small Mammals, Birds, Reptiles and Amphibians, and Terrestrial Arthropods. Aquatic organisms are discussed in the Aquatics section (3.5).

3.4.1 Big Game

3.4.1.1 Rationale

3.4.1.1.1 Mule Deer Movement

Prior to baseline studies the existing information on the migratory patterns of deer in the Piceance Basin suggested that a study was needed regarding these large scale movements as they relate to the Tract C-b area. The baseline study design placed emphasis on two aspects of deer migratory behavior: 1) the local routes used by deer during fall and spring migrations, and 2) the timing of these migrations. It was also considered important to determine whether critical travel routes exist on Tract C-b in order to avoid disturbing these areas if possible.

In addition to deer migration studies the local movement patterns of deer on winter range were also investigated. Studies were designed to describe deer movement and distributions during winter months in order that any major changes due to future development activities might be detected.

3.4.1.1.2 Mule Deer Habitat Utilization

The quantification of deer habitat utilization was approached by obtaining data on deer fecal pellet-group densities in representative habitat types, and by studies of the intensity of browsing by deer on key browse plants. Both studies emphasized evaluating the importance and condition of the habitat rather than estimating deer population size. Information on deer pellet-group densities was considered valuable particularly for estimating relative deer use of the major habitat types that occur in the Tract study area and for comparing trends in relative deer numbers in these same areas over time. The condition of key browse plants was considered valuable primarily for evaluating the wintering deer herd in terms of the carrying capacity of the range.

3.4.1.1.3 Mule Deer Mortality Studies

Studies of deer mortality were conducted on the Tract C-b study area primarily to evaluate the relative importance of the various habitat types to over-wintering deer. It was assumed that higher mortalities in a given habitat would be indicative of a habitat providing more available food and more effective cover, since deer tend to seek out such areas during the more stressful periods of winter (Ozaga and Gysel 1972). An estimate of the total number of deer deaths that occurred each winter within Tract boundaries was not a principal concern. Age class estimates were obtained to provide additional information on fawn mortality.

3.4.1.2 Objectives

3.4.1.2.1 Mule Deer Movement Patterns

The objectives of studies concerning deer migrational events were 1) to describe the spatial pattern of the fall and spring deer migration as it occurs in the vicinity of Tract C-b and 2) to determine the timing of the fall influx and the spring egress.

The objectives of local deer movement studies were 1) to describe seasonal shifts in deer distributions at the lower elevations (road count studies) and 2) to describe general patterns of deer distributions in areas of difficult access (aerial reconnaissance studies).

3.4.1.2.2 Mule Deer Habitat Utilization

The objectives of deer habitat utilization studies were 1) to obtain estimates of deer pellet-group densities in order to estimate the relative numbers of deer in various habitat types, 2) to obtain estimates of production and utilization of key browse species by shoot length measurements, and 3) to obtain estimates of general browse conditions using ocular methods.

3.4.1.2.3 Mule Deer Mortality Studies

The primary objective of the deer mortality study was to compare differences in the number of deer mortalities among five habitat types within the Tract C-b study area.

3.4.1.3 Experimental Design

3.4.1.3.1 Mule Deer Movement Patterns

Deer migration routes were quantitatively evaluated by track counts conducted on top of the major north-south ridges which occur on and adjacent to Tract C-b. Counts were conducted once in the fall and once in the spring. It was necessary to anticipate the timing of both migrations, which became possible after the first season of investigation.

Road counts used for local deer movement studies were conducted from Little Hills Game Experiment Station to Rio Blanco, a distance of 36 miles. Aerial reconnaissance flights were conducted over Tract C-b and the area extending approximately five miles outside Tract boundaries. This expansion of the study area was considered necessary in order that the dynamics of deer movements on Tract C-b could be viewed within a broader geographic context.

3.4.1.3.2 Mule Deer Habitat Utilization

Pellet-group counts were conducted in three major habitat types, pinyon-juniper woodland, chained rangeland, upland sagebrush, and the pinyon-juniper/bottomland sagebrush ecotone. Counts were conducted during the spring of 1975 and 1976. Studies of browse production and utilization by shoot measurements were conducted in pinyon-juniper and chained rangeland habitats during the spring of 1976. Ocular estimates of browse condition were obtained for mountain mahogany, bitterbrush, serviceberry, and big sagebrush during 1975 and 1976.

3.4.1.3.3 Mule Deer Mortality Studies

Carcasses of deer that had died on the Tract C-b study area were examined in five habitat types during May and June of 1975 and 1976. Each carcass found was examined and its age and the time since death estimated. Differences among the five habitats were evaluated in terms of the number of carcasses found within quadrats of known size.

3.4.1.4 Brief Methodological Description

3.4.1.4.1 Mule Deer Movement Patterns

Track count studies designed to evaluate the major ridges as deer migration routes were conducted as follows: During September and October 1975; six ridges were selected; four inside Tract boundaries and two within the one-mile surrounding zone, one east and one west of the Tract. Five parallel transect lines were established on top of each ridge perpendicular to the contour at two-tenth mile intervals. Each transect was 90 meters (m) long and consisted of 10 circular quadrats (1 m^2 each) spaced 10 m apart. Quadrats were positioned on bare ground, which was raked free of tracks following each observation. The relative use of each ridge by the deer moving into the Tract area during the fall influx was estimated over a 24-day period involving 10 sampling days. An index of relative deer use was calculated as a percent frequency (number of quadrats with tracks divided by the total number of quadrats).

In addition to the above method, a second method was employed in the fall and again during spring. At the time of estimated maximal migratory movement a count was made of deer tracks that crossed a continuous, 1 kilometer (km) transect line. One transect was used on each of the same six ridges and in the same general locations as were used for the quadrat method previously described. All transects were located in what was judged to be homogeneous pinyon-juniper woodland at approximately 7000 ft. (2133 m) elevation.

Road count studies were conducted during late evenings. Numbers of deer were recorded for each 1-mile interval, with notations made of the deer observed feeding in agricultural meadows, on south-facing slopes, and on hay stacks; habitat occurrence was not noted if deer were moving. Counts were not conducted during inclement weather or prior to two hours before sunset.

Fixed-wing aerial reconnaissance flights were conducted monthly, from December 1974 to April 1975. All deer counts were made shortly after a fresh snowfall. During each flight, eight transects were flown perpendicular to the major ridges of the area (a generally east-west direction) at approximately 500 ft. (152 m) above ground level. The distributional pattern of deer throughout this area was based on the abundance of fresh deer tracks. Abundance was ranked as none, low, medium, high, or very high for ridge tops, slopes, and valleys.

3.4.1.4.2 Mule Deer Habitat Utilization

3.4.1.4.2.1 Pellet-group Counts

Pellet-group counts were obtained by counting the number of distinct pellet-groups occurring within 0.01 acre (.004 hectare) circular plots. Fifty plots, spaced at 50 ft. (15.2 m) intervals, comprised a transect 2450 ft. (746.7 m) long. Sixteen transects were used for 1975 counts; seventeen transects were used for 1976 counts (Appendix IV-A, Section A.4.1.1.1).

Transects were located in what was judged to be a representative habitat, and were positioned such that they cut across varying topography (Robinette et al. 1958). All plots were raked free of pellets in the fall prior to the arrival of deer from summer range. Pellet-group counts were then made in spring after the deer had left winter range. Pellet-groups were recorded when more than one-half of the group was within the quadrat.

3.4.1.4.2.2 Browse Production and Utilization by Shoot Measurements

Shoot length measurements of key browse species were taken inside and outside the fenced exclosures during the spring of 1976. The exclosures are located in the pinyon-juniper woodland and chained rangeland habitat types. The mean linear amount of new shoot production (1975 growing season) was estimated for mountain mahogany, bitterbrush, and serviceberry by measurements taken within the exclosures prior to the initiation of 1976 growth. An estimate of the amount of new shoot length consumed by deer during the winter (October-May 1975-1976) was obtained by subtracting the means of shoot length measurements taken on these same browse species outside the exclosure. Shoot length measurements from inside exclosures were obtained from all key shrubs judged to be representative; shoot length measurements outside exclosures were obtained by selecting the nearest shrub at 10 m intervals along transects located near the exclosures. Stems were chosen by selecting the stem judged to be most accessible to deer that occurred within a randomly chosen quarter of the shrub.

In September 1976 clipping studies were initiated to obtain weight estimates of new shoot production. Estimates were obtained for mountain mahogany and bitterbrush in two habitat types, pinyon-juniper woodland, and chained rangeland. This study is described in Section 3.3 (Vegetation).

3.4.1.4.2.3 Browse Condition Using Ocular Methods

Evaluations of general browse condition were made within the same 0.01 acre plots that were used for the pellet-group counts described above. Four key browse species were evaluated during both years of study, mountain mahogany, bitterbrush, serviceberry, and big sagebrush. The condition of these key browse plants was based on a subjective evaluation of the amount of new shoot production that had been consumed by deer during the previous fall-spring period. The estimated average condition of each key browse species within each plot was ranked as heavy (more than 50 percent of new shoot production consumed), moderate (10 to 50 percent consumed), light (a trace to less than 10 percent consumed) and none, as described by Aldous (1944). Criteria of availability followed Patton and Hall (1966).

3.4.1.4.3 Mule Deer Mortality Studies

Stratified random sampling methods were used, the strata being the following habitat: pinyon-juniper woodland, chained rangeland, bottomland sagebrush, agricultural meadows, and adjacent bottomland sagebrush, and lateral draws. Quadrats were randomly positioned within most of these units using aerial photographs to pinpoint locations. Lateral draws suitable for sampling were subjectively chosen in the field; the smaller draws and those with atypical habitat features were not sampled. Sizes of quadrats were generally 4 hectares (ha), the lateral draw quadrat size averaging 0.21 ha. Data on carcasses were gathered only when at least the skull, pelvic girdle, or one mandible was present. Criteria used to estimate the time since death were based on the appearance of bone, hair, and connective tissue. Carcass decomposition rates were established using time sequence photographs taken of fresh deer carcasses found within the study area. The age of the deer at time of death was estimated by toothwear criteria (Robinette et al. 1957). Fawn-adult ratios were obtained from agricultural meadows. Yearlings were classed as adults.

3.4.1.5 Results and Discussion

3.4.1.5.1 Mule Deer Movement Patterns

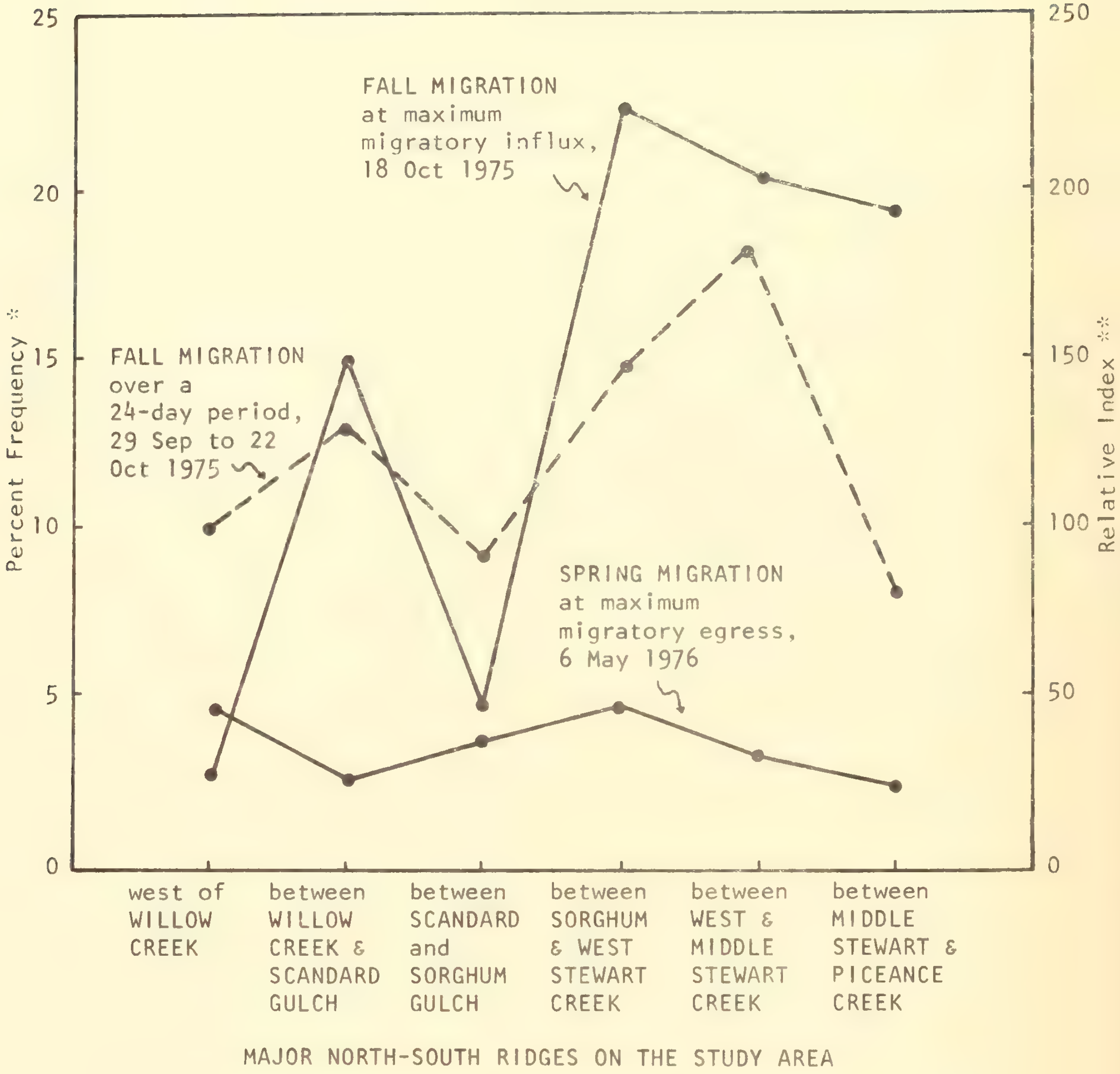
For approximately four months of the year, from mid-May to mid-September, deer are virtually absent from Tract C-b. By mid-October, however, large numbers of deer occur in the area. Following the fall migratory influx, and until the time of the spring migratory egress, many deer winter on Tract C-b and in the immediate vicinity. In terms of the Tract's location with respect to migrating deer, baseline studies have indicated that Tract C-b is located within deer winter range and not on a travel route between summer and winter ranges.

While deer are wintering in the Tract area their use of different habitat types changes considerably, which, in part at least, is due to weather conditions and available forage. In October and November conspicuous concentrations of deer occur in the agricultural hay meadows immediately north of the Tract C-b boundary. From December through February deer are mostly absent from these meadows, and for much of the mid-winter period they tend to occur in nearby upland sites of pinyon-juniper woodland, upland sagebrush, and chained rangeland. During times of deep snow, and particularly when snow drifts become crusted, many deer utilize the low elevation south-facing slopes, which melt free of snow sooner than other areas. In spring, at the time grasses and forbs initiate new growth, the deer again occur in the agricultural meadows, but within a matter of several weeks these large concentrations disperse and the deer move out of the Tract area to higher summer range.

The results of studies designed to evaluate the use of the major ridges as migration routes leading into the Tract area indicate that all ridges studied are traveled by the deer, although some are apparently used more heavily than others (Figure 3-4-1). During the fall, results indicated that the ridges east of Willow Creek and to either side of the West Fork of Stewart Creek were the most heavily used. During the spring migration, variation in the indices of deer abundance on the six ridges was less pronounced. Although valley bottoms were not systematically evaluated for tracks, observations indicated that comparatively few deer use these areas during major migratory movements. The conclusion reached is that migrating deer tend to travel along the large, continuous ridges that descend from higher elevations to the south, and that no one ridge constitutes a critical migratory pathway. To what extent the local wintering deer herd moves into the Tract area from the north is unknown.

The duration of the spring and fall migratory movements, as observed on the study area, is approximately two weeks. The peak periods of movement occurred on 18 October 1975 and 6 May 1976. Both dates are approximately one week earlier than were observed the year before.

To some extent deer migratory events can be inferred from the results of road count studies. As mentioned, the agricultural hay meadows are attractive to the deer in the fall, and it is clear from general field observations that large numbers of deer utilize these areas immediately upon arrival from higher elevations. During October, for example, soon after deer are first seen in the Tract area, groups totaling 50 or more deer are typically recorded for the meadows to the north of Tract boundaries (Figures 3-4-2 and 3-4-3). The abruptness of the spring migration is exemplified by the results of concurrent road count and track count studies. Road counts for the Willow Creek meadow to the north-west of Tract C-b (Figure 3-4-4) were conducted in addition to the longer 36-mile counts (Figures 3-4-2 and 3-4-3) to estimate the peak period of the spring migratory egress. On 6 May the track counts previously described (Figure 3-4-1) were conducted on the higher pinyon-juniper ridges approximately 5 miles to the south. On 12 May these counts were repeated on three of the same ridges (those between Scandard Gulch and Middle Stewart Creek) to determine



*	Dashed line:	Number of quadrats with tracks/No. of quadrats sampled x 100.
**	Solid line:	Number of tracks which crossed a 1-km transect.

Figure 3-4-1 RELATIVE NUMBERS OF DEER TRACKS ON THE MAJOR RIDGES DURING FALL AND SPRING MIGRATIONS. ALL SAMPLING LOCATIONS OCCURRED IN PINYON-JUNIPER WOODLAND AT APPROXIMATELY 7000 FT. (2133m) ELEVATION.

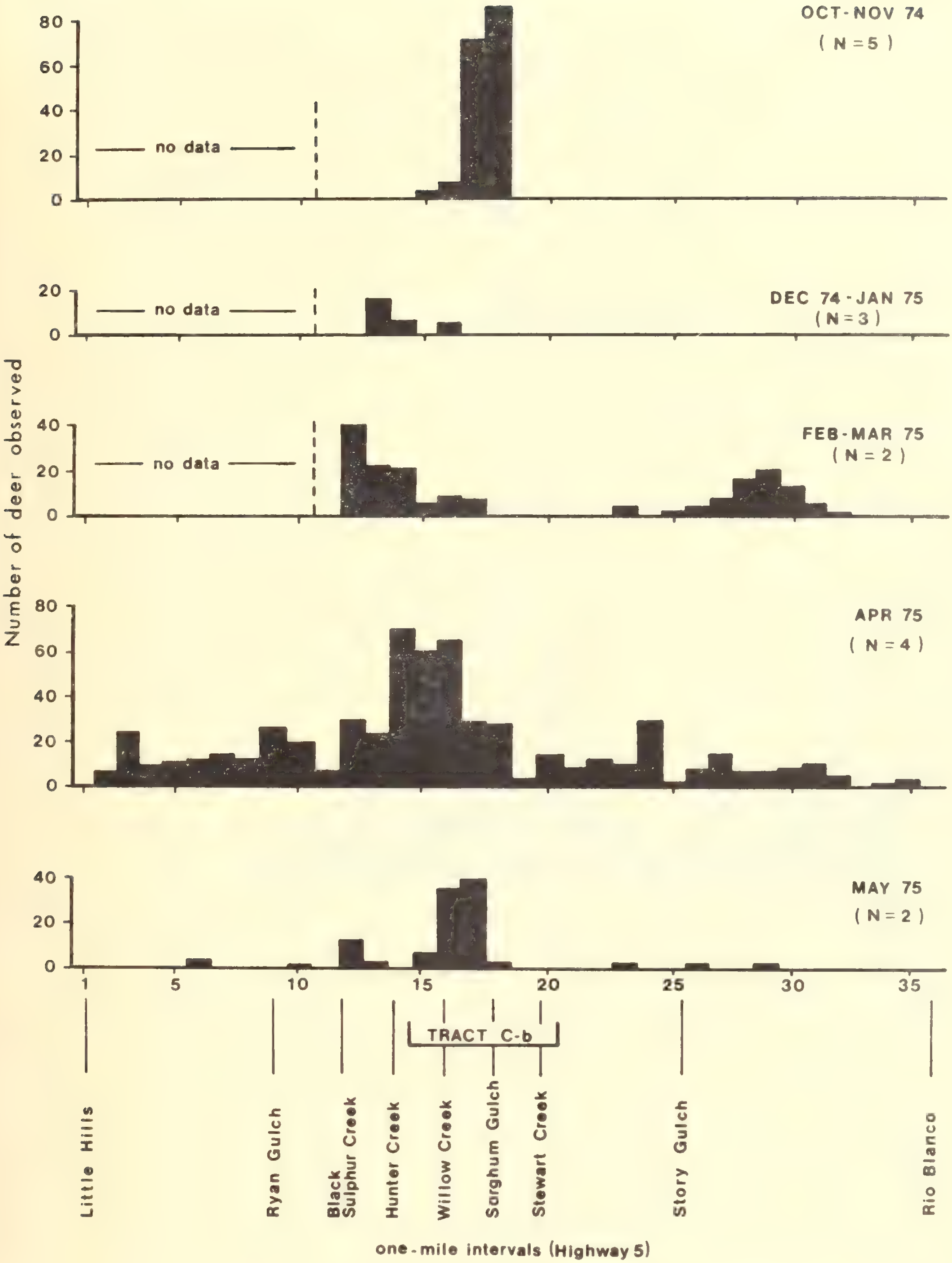


Figure 3-4-2 SUMMARY OF DEER ROAD COUNTS FOR FIRST YEAR OF BASELINE STUDY. HEIGHTS OF BARS ARE MEANS; SAMPLE SIZES (N) ARE THE NUMBER OF ROAD COUNTS FOR THE PERIOD.

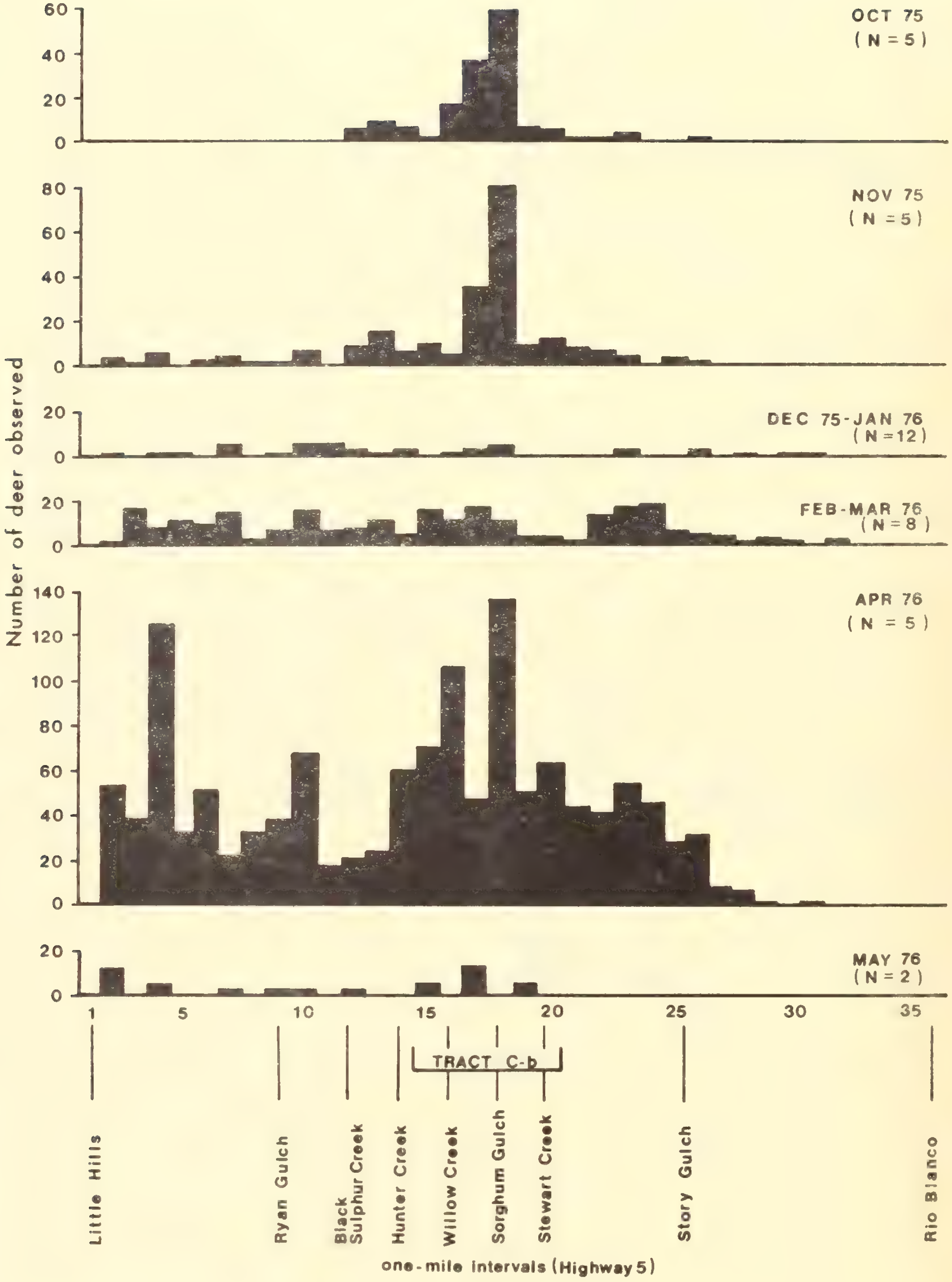


Figure 3-4-3 SUMMARY OF DEER ROAD COUNTS FOR SECOND YEAR OF BASELINE STUDY.

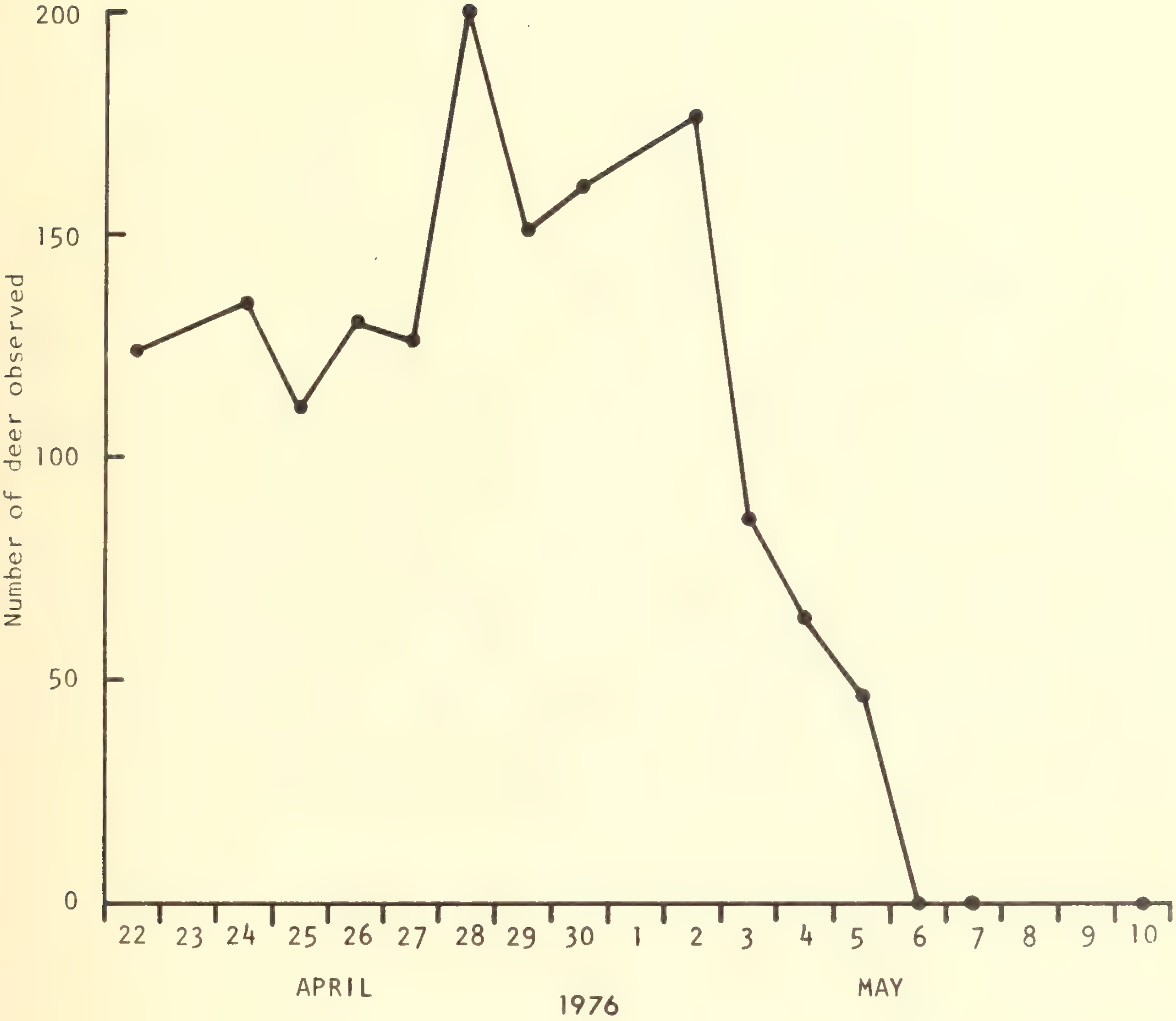


Figure 3-4-4 DEER ROAD COUNTS IN THE WILLOW CREEK MEADOW NEAR TRACT C-b. THE DOWNWARD TREND MARKS THE BEGINNING OF THE SPRING DEER MIGRATION OF 1976.

whether many deer remained at these elevations. The number of tracks crossing these transects on 6 May was 35, 47, and 30 (Figure 3-4-1); on 12 May the number of tracks observed was 0, 3, and 9 indicating that most of the deer had moved out of the Tract area to higher summer range. The virtual absence of deer throughout the remaining summer months is based on field observations and track count results (Appendix IV-B, Table B-4-1).

The local movement patterns of deer throughout the fall-spring period were studied mainly by road count and aerial reconnaissance methods. Additional information was obtained by unstructured field observations, and by deer mortality studies to be detailed in a later section.

During the initial stages of baseline studies, road counts were conducted only within the immediate vicinity of Tract C-b. It was soon evident, however, that large numbers of deer use the agricultural meadows within the study area, and that these local concentrations should be compared with the concentrations along the main highway to either side of the Tract. All subsequent road counts were then routinely conducted over a 36-mile length of highway, from Rio Blanco to Little Hills Game Experiment Station which, in effect, is a transect extending nearly across the Piceance Basin. The habitat through which it travels is similar over most of its length, with irrigated agricultural meadows and pastures typically adjacent to the road and pinyon-juniper uplands nearby.

The results of the two years of deer road count studies (Figures 3-4-2 and 3-4-3) show several obvious patterns. As mentioned, the fall and spring periods are the times that meadow concentrations occur. During the mid-winter period most of the deer that can be observed from the highway occur on south-facing bunchgrass slopes, in sagebrush, or on hay stacks within the meadows. These changes in habitat occurrence imply major changes in forage utilization (Figure 3-4-5).

Changes in habitat use on upland sites were more difficult to quantify by direct observation than were the conspicuous changes that could be noted during road counts. The results of aerial reconnaissance flights (Figure 3-4-6), however, characterize the general patterns. These results are of particular interest in terms of depicting the dynamics of the upper elevation limits of deer winter range, which change seasonally and in all probability from year to year depending on the severity of the winter and changing carrying capacity.

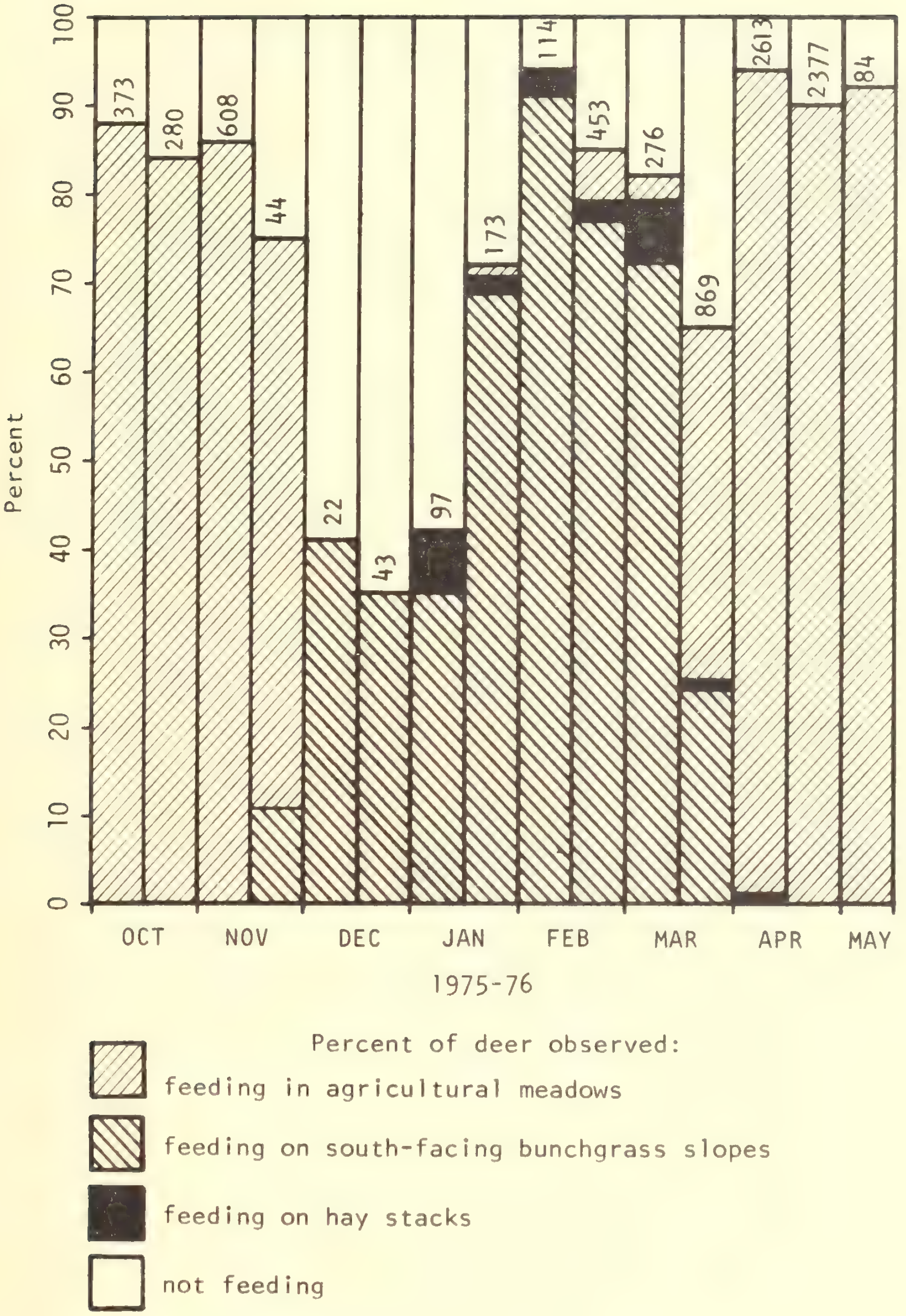
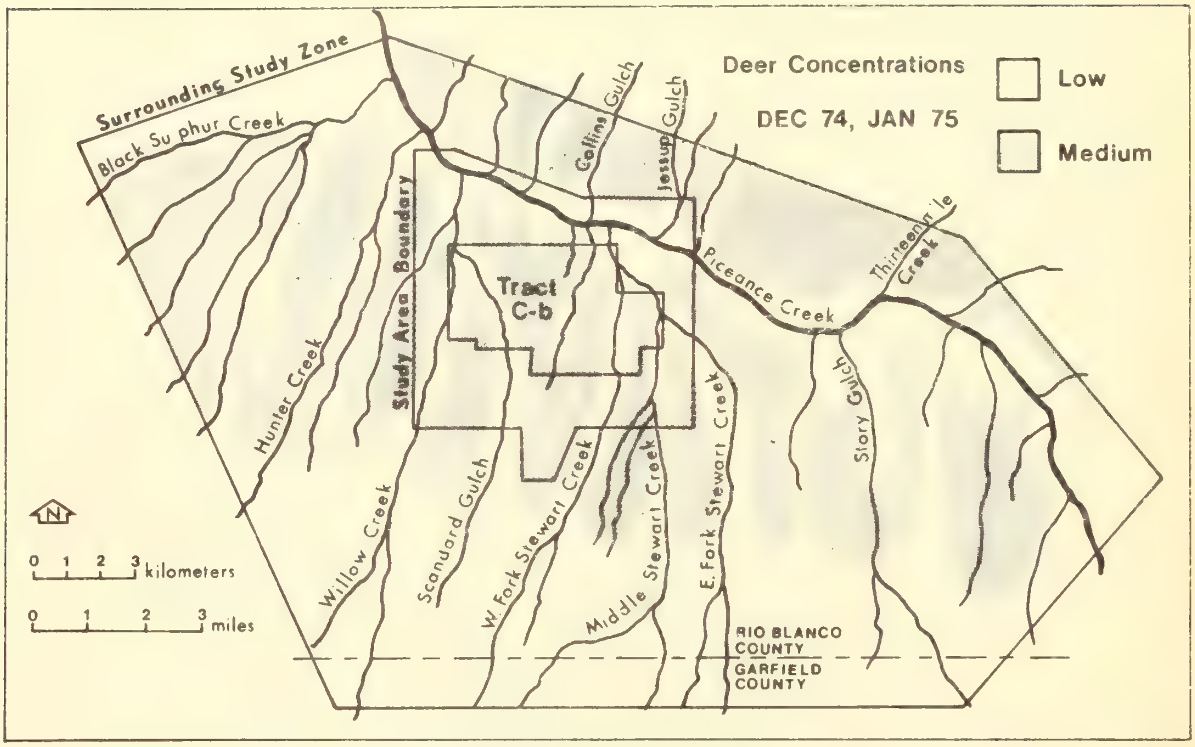


Figure 3-4-5. FEEDING ACTIVITIES OF DEER OBSERVED DURING EVENING ROAD COUNTS. TOTAL NUMBER OF DEER OBSERVED IS SHOWN ABOVE HATCHED BARS. DATA ARE GROUPED FOR TWO-WEEK INTERVALS.



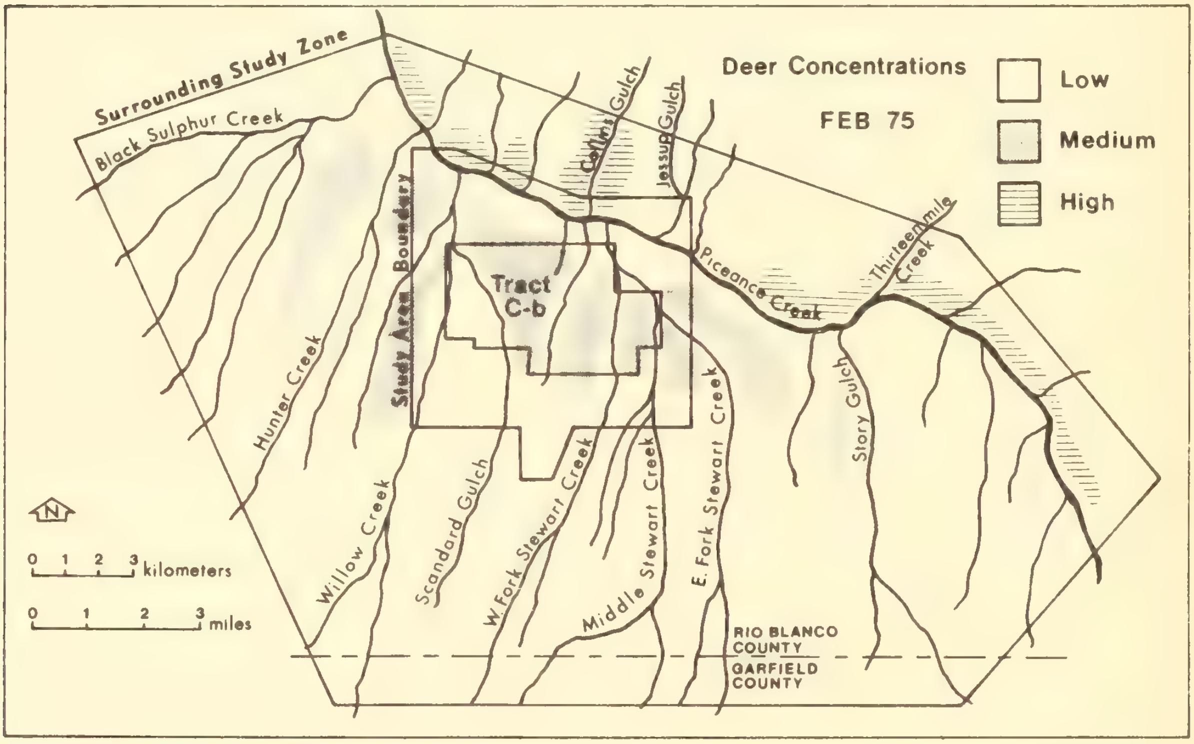


Figure 3-4-6 DEER DISTRIBUTIONS DURING MID AND LATE WINTER. OBSERVATIONS WERE MADE FROM FIXED-WING AIRCRAFT AFTER FRESH SNOWFALLS.

3.4.1.5.2 Mule Deer Habitat Utilization

Deer pellet-group counts for both years of the baseline study (Table 3-4-1) suggest the chained rangeland habitat is utilized more heavily in most cases than the other habitats sampled. The reason for the high pellet-group estimate for the upland sagebrush habitat during the first year of study is unknown. Results also suggest that more deer were present in the Tract area during the second year of baseline study.

The above generalizations were varified statistically using a single-factor analysis of variance and the Student-Newman-Keuls multiple range test (Zar 1974). The higher pellet-group densities estimated for chained areas when compared to pinyon-juniper areas were statistically significant both years ($P<.005$). In addition, pellet-group densities were significantly higher for both the chained and the pinyon-juniper habitats during the second year ($P<.05$). Analyses were restricted to the chained and pinyon-juniper habitats because of sampling problems associated with the upland sagebrush and pinyon-juniper/bottomland sagebrush habitats.

The large sample size used for the pinyon-juniper woodland permitted partitioning sampling plots into arbitrary elevational units while retaining adequate sample sizes ($SE<10$ percent of $\bar{X}$). Pellet-group densities were significantly higher at the lower elevations (approximately 6500 ft., 1981 m) than at the upper elevations (approximately 7200 ft., 2194 m) for 1975-76 ($P<.05$), suggesting that varying intensities of winter range use occur as a function of elevation (snow depth?) as well as habitat type. Differences were not significant, however, during 1974-75. The above statistical analyses employed standard t-test procedures, with a log transformation of the data used to adjust for positive skewness. Variance-mean ratios are shown in (Table 3-4-1) and in all cases suggest clumped distributions.

While the estimates of pellet-group densities for the various habitat types are useful as indicators of relative habitat importance, it must be kept in mind that the value to deer of areas used principally for cover and little for feeding will tend to be underrated by these methods. Field observations indicate that this consideration applies to the pinyon-juniper woodland habitat particularly.

Studies concerning key browse species provided information on mountain mahogany, bitterbrush, serviceberry, and big sagebrush. These species were assumed to be the key browse species on Tract C-b based on studies at Little Hills Game Experiment Station (McKean and Bartmann 1971), which is located approximately 10 miles north of the Tract. The importance of other plant species to deer diet was not determined.

Table 3-4-1

DEER PELLET-GROUP DISTRIBUTIONS AND DENSITIES.

Habitat Types	Mean pellet-groups/acre ± SE	No. of pellet groups	Deer-days utilization/acre*	No. of deer/acre**	No. of 0.01 acre plots	Surface area of habitat type on entire study area. (On Tract C-b)	Sampling intensity percent***	$S^2/\overline{X}$
Pinyon-juniper woodland								
1974-75	260±14	1138	20	0.10	437	1528	0.28%	3.26
1975-76	373±17	1629	29	0.14	437		0.28%	3.51
Chained rangeland								
1974-75	377±27	687	29	0.14	182	1557	0.12%	3.39
1975-76	475±33	860	37	0.18	181		0.11%	4.15
Upland sagebrush								
1974-75	534±44	470	41	0.20	88	528	0.16%	3.23
1975-76	338±32	297	26	0.13	88		0.16%	2.65
Pinyon-juniper/bottomland sagebrush ecotone								
1974-75	276±35	257	21	0.10	93	279	0.33%	4.08
1975-76	286±25	409	22	0.11	143		0.51%	3.01
Above habitats combined								
1974-75	319±12	2552	25	0.12	800	3892	0.89%	3.61
1975-76	376±13	3195	29	0.14	849		1.06%	3.65

*Calculated as mean pellet-groups per acre ÷ 13 (the average number of pellet-groups/deer/day; Smith 1974).
**Calculated as deer-days utilization ÷ 201 (the number of days that deer were on winter range).
***Calculated as sample plot area : area of habitat type on study area.

Shoot length measurements taken in the spring of 1976 from inside and outside exclosures provides estimates of the percent of new shoot length consumed by deer during the winter of 1975-76 (Table 3-4-2). As such, these estimates provide a quantitative expression of shrub condition and, assuming key importance of the three species sampled, an approximation of how near the local wintering deer herd is to carrying capacity. According to Shephard (1971) optimal utilization of these three browse species is about 70 percent for mountain mahogany, 50 percent for bitterbrush, and 60 percent for serviceberry. Although these estimates were obtained for a different geographic location (southwestern Colorado) and for a summer-fall use period, they seem applicable since they are in general agreement with similar studies. Steinhoff (1959), for example, found 50 percent to be near the optimal level for bitterbrush in northern Colorado, and Bartmann and McKean (1969) reported that 58 percent utilization of mountain mahogany, 55 percent of bitterbrush, and 38 percent of serviceberry was not detrimental at Little Hills. On the basis of these studies the data shown in Table 3-4-2 suggest that wintering deer on Tract C-b are near carrying capacity. It should be noted that the estimates for mountain mahogany are questionable because of sample size (few plants were present inside the enclosures), and that serviceberry is not very common in the study area. Data on bitterbrush, however, are considered adequate and to be the best indicator of range use. Estimates of bitterbrush utilization for both the pinyon-juniper and chained rangeland habitats exceed the above estimated optimal levels.

Browse condition studies based on ocular methods are more subjective than shoot length studies, but they have the advantage of providing information from more sampling locations. The results of this study (Table 3-4-3) show most shrubs classified as heavily browsed and, therefore, are indicative of deer use above optimal levels.

The conclusions of both browse studies are supported by the estimates of deer-days use obtained from pellet-group data (Table 3-4-1). McKean and Bartmann (1971) maintain that deer stocking rates of 15 to 20 deer-days per acre at Little Hills would probably result in over utilization of the key browse species. The deer-days per acre estimates obtained for Tract C-b (Table 3-4-1) exceed 15 to 20 deer-days per acre in almost every case.

3.4.1.5.3 Mule Deer Mortality Studies

The habitats within the Tract C-b study area where most deer mortalities occurred during baseline studies were the

Table 3-4-2 MULE DEER BROWSE UTILIZATION, 1975-76

	Pinyon-juniper woodland			Chained rangeland		
	Mt. mahogany	Bitterbrush	Serviceberry	Mt. mahogany	Bitterbrush	Serviceberry
1975 shoot production (mm)						
Mean ± SE	124±36	106±5	67±7	215±20	151±7	99±10
Sample size	18	100	85	47	50	50
Shoot growth remaining in spring, 1976 (mm)						
Mean ± SE	23±2	37±3	43±4	96±6	43±3	73±8
Sample size	80	30	80	50	150	50
Percent utilization[1]	82%	65%	36%	56%	72%	26%

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[1] Calculated as shoot production minus growth remaining in spring ÷ shoot production x 100.

Table 3-4-3 BROWSE CONDITION BASED ON OCULAR METHODS OF EVALUATION

Shrub species	Intensity of browsing[1]							
	1974-75				1975-76			
	Heavy	Mod.	Light	None	Heavy	Mod.	Light	None
Mt. mahogany	117	2	1	0	147	9	1	0
Bitterbrush	173	3	0	0	180	1	1	0
Serviceberry	149	4	1	2	81	40	9	7
Big sagebrush	217	127	149	27	159	133	174	59

[1] Calculated as the mean of rank values. Each shrub species was evaluated when encountered within sample plots. Number of plots sampled was 800 for 1974-75, 849 for 1975-76.

Estimated amount of new shoot production consumed	Rank value
more than 50%	heavy = 70
10 to 50%	moderate = 30
trace to less than 10%	low = 5
no evidence of browsing	none = 0

lateral draws and the topographically similar bottomland sagebrush areas that are adjacent to the agricultural meadows along Piceance Creek (Table 3-4-4). These results support field observations conducted during snow storms and during times of deepest snow cover when many deer were observed remaining in the shelter of these draws. During such times deer frequently can be observed feeding on a slope that has melted free (typically a south-facing bunchgrass slope) or moving with difficulty through snow drifts that partially cover the more nutritious browse plants. The fawns have more difficulty plunging through the drifts than the does, which causes many to weaken and die.

The frequency of deer carcasses in the five habitats sampled were remarkably similar for the two years of study (Table 3-4-4). A statistical analysis of these data was performed to evaluate the significance of the differences observed. When subjected to a G-test (Sokal and Rohlf 1969) the hypothesis that carcasses occur randomly throughout the five habitat types was rejected ($P<.001$). Subdividing the G-test indicated no differences among the pinyon-juniper woodland, chained rangeland, and bottomland sagebrush habitats ($P<.25$), but significantly more carcasses in the combined lateral draw and agricultural/sagebrush habitats ($P<.001$) and significantly more carcasses in the lateral draws than in the agricultural/sagebrush habitats ($P<.001$ for 1974-75; $P<.05$ for 1975-76). No statistical differences could be detected comparing differences between years.

During the first year of baseline study, deer carcasses were recorded for each habitat sampled in terms of deaths of the current winter (1974-75), and deaths which had occurred during previous years. When these data were combined, and considering only the carcasses that could be aged, 76 percent of the carcasses were fawns (N=246). The age-class ratios for both years (Table 3-4-5) indicate a decline in fawns between the fall and spring periods (November to April) of approximately 50 percent for both years. The ratio of fawns to adult deer was considerably higher during the 1974-75 season, however, indicating that reproductive success was greater during the first year of baseline study.

The generally high incidence of fawns in these counts may not reflect the actual age structure of the local deer population. This bias is considered entirely possible, since the higher, more accessible areas were not sampled and the segment of the deer population in these areas at the time of sampling may have had a larger component of adult deer. This sampling limitation is not likely to adversely affect estimates of trends in reproductive success or fawn mortality.

Table 3-4-4 DEER MORTALITY RESULTS

	1974-1975				1975-1976			
Habitat Type	No. of carcasses found	No. of hectares sampled (No. acres)	No. of carcasses/ hectare (per acre)	No. of carcasses expected if randomly distributed	No. of carcasses found	No. of hectares sampled (No. acres)	No. of carcasses/ hectare (per acre)	No. of carcasses expected if randomly distributed
Pinyon-juniper woodland	4	32 (79)	0.13 (0.05)	7.8	3	32 (79)	0.09 (0.04)	7.5
Chained rangeland	4	32 (79)	0.13 (0.05)	7.8	1	32 (79)	0.03 (0.01)	7.5
Bottomland sagebrush	1	16 (40)	0.06 (0.03)	3.9	2	16 (40)	0.13 (0.05)	3.8
Agricultural meadows and adjacent bottomland sagebrush	9	32 (79)	0.28 (0.11)	7.8	14	32 (79)	0.44 (0.18)	7.5
Lateral draws	11	7.25 (18)	1.52 (0.61)	1.8	8	7.25 (18)	1.10 (0.44)	1.7
Totals	29	119.25 (295)			28	119.25 (295)		

Table 3-4-5. AGE-CLASS COMPOSITION OF DEER WINTERING NEAR TRACT C-b

Date	Fawns	Adults	Fawns/100 adults
19 Nov. 1974	89	67	133
24 Mar. 1975	141	154	92
19 Apr. 1975	82	103	80
3 May 1975	85	113	75
21 Nov. 1975	36	32	113
28 Feb. 1976	61	88	69
15 Apr. 1976	196	299	66

3.4.1.5.4 Elk

A few elk were present near the eastern boundary of the study area during March 1975. Occasionally, during the course of field investigations, elk fecal pellets were observed within the boundaries of the Tract, and most commonly in the pinyon-juniper and mixed mountain shrub habitats. Most of the fecal pellets observed were old and they were not abundant at any site. Small groups of elk were seen on several occasions during July and August 1975 at higher elevations to the south of the study area.

3.4.2 Medium-sized Mammals

3.4.2.1 Rationale

Medium-sized mammals were defined as those species ranging in size from cottontails to coyotes. Studies concerning these species emphasized obtaining information which would permit the recognition of 1) those species that are significant in terms of energy flow within the ecosystem (the abundant predators and prey), 2) the rare and perhaps vulnerable species, and 3) those species of aesthetic, economic, or scientific interest.

3.4.2.2 Objectives

The major objectives of the medium-sized mammal studies were 1) to obtain an accurate species list, 2) to identify the significant species (based on ecologic, economic or, aesthetic criteria), and 3) to quantify the abundance of these species to the extent possible.

3.4.2.3 Experimental Design

Scent station lines were used to quantify the relative abundance of coyotes. Transect lines were located in the valleys of Stewart Creek and Scandard Gulch. Sampling periods occurred in September of 1974 and 1975.

Track count methods were employed for obtaining indices of medium-sized mammals as well as coyotes. Information was obtained on habitat affinities by sampling within four habitat types: pinyon-juniper woodland, chained rangeland, bottomland sagebrush, and agricultural meadow.

Identifications of medium-sized mammals were based on direct observations except for two species, the bobcat and badger, which were identified on the basis of tracks.

3.4.2.4 Methods

Methods used for coyote scent station lines follow those presently being used by the U. S. Fish and Wildlife Service (Linhart and Knowlton 1975). A coyote scent station line is a 50-station transect 15 miles (24 km) long. Each station consists of a 3-ft. (0.9 m) circle of sifted earth with a capsule containing an olfactory attractant placed in the center. Stations were placed at three-tenth mile intervals along ranch roads. These lines were checked for the presence of coyote tracks for 5 successive days in 1974 and for 3 successive days in 1975. A relative index of abundance was calculated as a visit frequency: the number of stations with tracks divided by the number of "operable" stations times 1000. An operable station is one that has not been disturbed by cattle, wind, or other factors.

The bi-monthly track counts were conducted along transect lines consisting of 20 quadrats, $4m^2$ each, placed at 25 m intervals. Lines were positioned through homogeneous habitat with quadrats placed on bare ground nearest the 25 m location. The bare areas were raked free of large debris, and fine soil sifted over the quadrat when necessary. These preparations were made in evenings and counts were made the following morning. During the snow-free season one transect was used in each of the four habitat types. When there was a fresh snow cover the number of transects in each habitat type was increased to four, no preparation of the lines being necessary. All quadrats were purposely positioned to avoid animal trails. No olfactory attractant was used for bi-monthly track counts. A relative index of abundance was calculated for each species by dividing the number of quadrats with tracks of that species by the number of operable quadrats.

3.4.2.5 Results and Discussion

Results of the coyote scent station study (Table 3-4-6) suggest that coyotes are abundant near Tract C-b compared to elsewhere in Colorado, Utah, and Wyoming. The high numbers of coyotes may be partially due to the abundance of deer, coupled with minimal predator control in nearby areas. Personal interviews with local cattle ranchers suggest that few coyotes are shot or trapped. Many deer are fed upon as carrion by coyotes during winter in the Tract study area, and several fawns were recognized as being coyote kills. Although carrion feeding is likely to be a significant factor in sustaining the coyote population throughout the winter, the importance of coyote predation on deer, or on other potential prey species, was not determined. Coyotes may kill appreciable numbers of new born fawns, but the

Table 3-4-6 RESULTS OF COYOTE SCENT STATION SURVEYS

Sampling Date	Indices of relative abundance			
	Tract C-b	Colorado[1]	Utah[1]	Wyoming[1]
September 1974	188	98.1	36.0	65.4
September 1975	122	74.4	24.6	74.2

[1] U.S. Fish and Wildlife Service, U.S.D.I. (1974 and 1975)

high fawn-adult ratios obtained in early fall (Table 3-4-4, Mule Deer Mortality Studies) suggested that this was not the case during the two years of baseline studies.

A summary of the results of the bi-monthly track count data is presented in (Table 3-4-7). Cottontail tracks were by far the most common tracks observed and, except for coyote tracks, the tracks of other medium-sized mammals were seldom observed.

The habitat with the highest abundance of cottontails, as indicated by the results of the track count method (Table 3-4-7), was the bottomland sagebrush. Abundance indices here, combining both years, was significantly higher than the combined results of the other three habitat types (P<.001); differences were not significant among the pinyon-juniper woodland, chained rangeland, and agricultural meadow habitat types (G-test; Sokal and Rohlf 1969).

Seasonal trends in cottontail abundance for both years show that highest numbers occur in late summer (Figure 3-4-7). Based on field observations, cottontail populations were judged to be low during the first year of baseline study (from October 1974 to September 1975) compared to other areas in Colorado with satisfactory desert cottontail habitat. A noticeable increase was observed, however, in the late summer of the second year of baseline studies. A statistical comparison of cottontail track frequency for the combined sampling periods of each year of baseline study demonstrated significantly higher frequencies for the second year (G-test; P<.001; Sokal and Rohlf 1969). Apparently, substantial reproduction occurred during the summer months of the second year based on the many field observations of young cottontails during July and August of 1976.

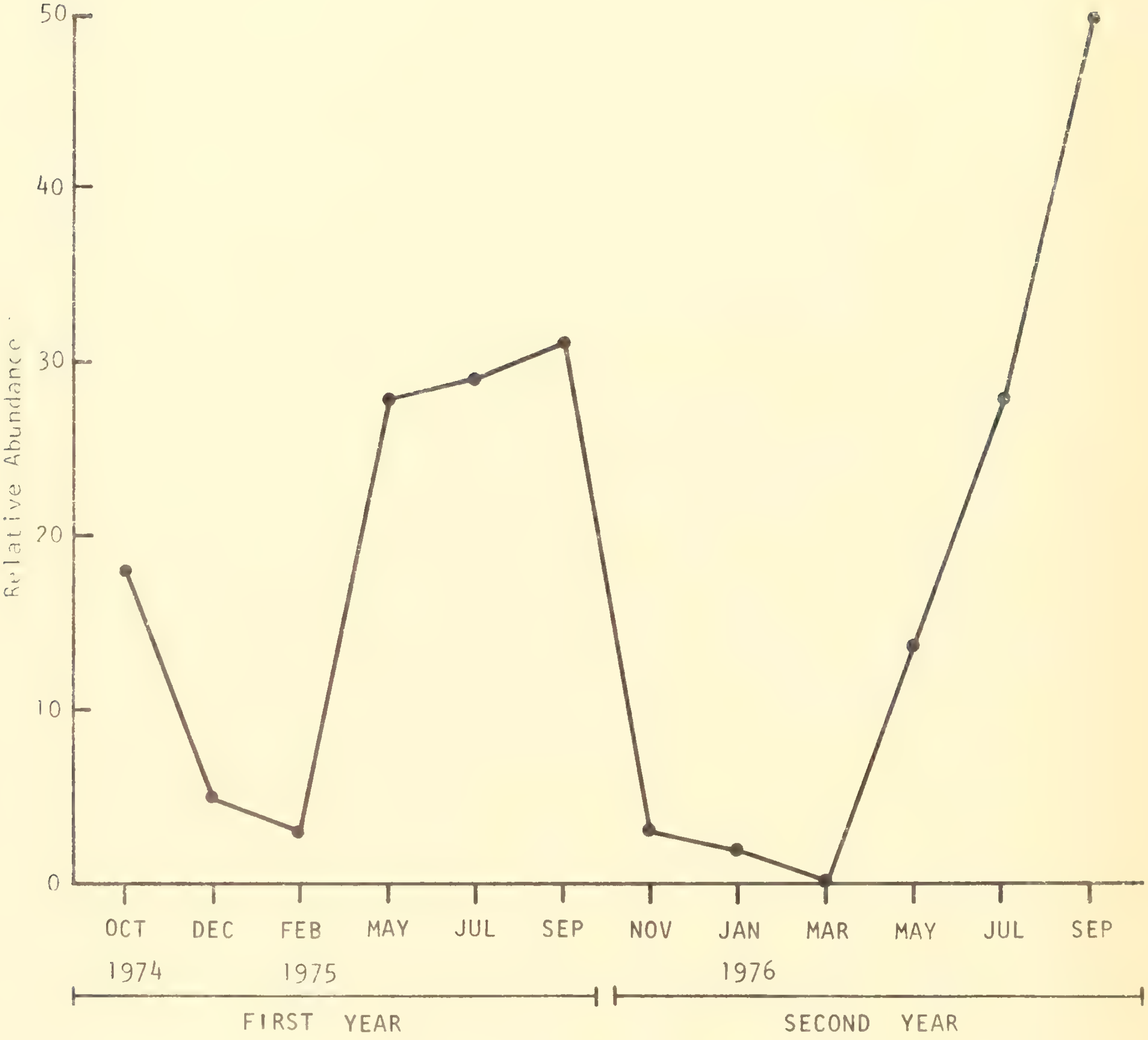
In terms of the second objective of the study, (Appendix IV-B, Table B-4-2) the indentification of significant species, several conclusions can be made. The coyote and cottontail, as suggested by the data already presented, should be considered significant components of the local food web. The coyote is a significant predator and the cottontail is a potentially significant prey species (further discussion of predator-prey relationships are presented in Vol. V, System Interrelationships). Both of these species are also potentially important economically. The cottontail is a game species, although presently it is seldom hunted near Tract C-b; the coyote can be an important predator of domestic sheep, but currently sheep are not grazed in the immediate vicinity of the Tract. The bobcat is the only other medium-sized mammal on the Tract C-b study area that is recognized as being significant in terms of the criteria being used here. This judgment is, of course, a matter of opinion, but it is based on field observations indicating a moderate to high population of bobcats on the Tract C-b study area, particularly in

Table 3-4-7 RELATIVE ABUNDANCE* OF MEDIUM-SIZED MAMMALS IN FOUR HABITAT TYPES AS ESTIMATED BY TRACK COUNTS. THE DATA COMBINE BI-MONTHLY SAMPLING PERIODS FOR EACH YEAR OF BASELINE STUDY.

	No. of quadrats sampled		Cottontail		Coyote		Jackrabbit		Porcupine		Bobcat		Long-tailed weasel		Racoon		Skunk		House cat	
	**yr.1	yr.2	yr.1	yr.2	yr.1	yr.2	yr.1	yr.2	yr.1	yr.2	yr.1	yr.2	yr.1	yr.2	yr.1	yr.2	yr.1	yr.2	yr.1	yr.2
Pinyon-juniper woodland	278	355	6.1	7.6	0.7	4.5	0.7	0	0.4	0	0	0	0	0.4	0	0	0	0	0	0
Chained rangeland	220	360	10.5	3.6	1.4	0.3	0	0	0	0	0	0	0	0.9	0	0	0	0	0	0
Bottomland sagebrush	177	359	26.6	10.0	10.2	2.5	0	0	0	0	0.6	0	0	0	0	0	0	0	0	0
Agricultural meadow	255	358	7.8	3.9	7.8	1.4	0	0	0	0	0	0	0	0	0.4	0	0.4	0	0.8	0

*Relative index of abundance is calculated as a percent frequency (No. of quadrats with tracks ÷ No. of quadrats sampled x 100).

**Year 1 of baseline study is from October 1974 to September 1975; year 2 is from November 1975 to September 1976.



* Calculated as a percent frequency based on track counts (No. of quadrats with tracks/No. of quadrats sampled x 100).

Figure 3-4-7 TRENDS OF COTTONTAIL ABUNDANCE ON TRACT C-b DURING TWO YEARS OF BASELINE STUDY.

the rimrock areas. The bobcat is an important predator, a highly aesthetic species to many, and presently a valuable furbearer.

Although the medium-sized mammals discussed below were identified within the study area, from track count studies and from unstructured field observations, information regarding their abundance and distribution was limited and precludes quantitative analysis.

All observations of jackrabbits permitting species identification were of the white-tailed jackrabbit. The black-tailed jackrabbit was not identified. Jackrabbits were rarely observed within the Tract C-b study area, and unquestionably they were not abundant during baseline studies. They appeared to be fairly common, however, at the higher elevations immediately south of the Tract. Jackrabbit tracks were recorded in eleven coyote scent stations with most occurrences in the mixed mountain shrub habitat type above 7500 ft. (2286 m) elevation.

Marmots were sighted within the study area on only two occasions during baseline studies. Both sightings were in the same agricultural meadow during May of 1976. Apparently a few individuals moved into the study area during the second year of baseline study. Marmots are common at a few locations in agricultural meadows several miles from the study area.

Muskrats were seen from time to time in the ponds and irrigation ditches along Piceance Creek. They seem not to be abundant, however. Cranial bones of muskrats were occasionally found near raptor nests.

No signs of beaver activity within the study area were observed during baseline studies, although one sighting of a beaver in Piceance Creek within the study area was reported. The nearest active beaver area observed was 10 miles upstream on Piceance Creek. This area appeared to be abandoned during the second year of baseline study.

Gnawed bark resulting from porcupine feeding activities is fairly common on pinyon trees within the study area. Porcupines were observed, however, on only two occasions. At the higher elevations south of Tract C-b porcupines are surprisingly numerous.

Striped skunks were observed only twice during baseline studies. No road kills were observed and tracks were infrequently found.

Tracks of the long-tailed weasel were identified on fresh snow on many occasions and several sightings were reported. Based on these observations, it appears that the long-tailed weasel is fairly common on Tract C-b. Most observations were made in the chained rangeland habitat.

Raccoon tracks were commonly found in the mud along Piceance Creek, and on one occasion at 7000 ft. (2133 m) within pinyon-juniper woodland. A local rancher claims that raccoons are more numerous now than during past years.

Badgers appear to be uncommon on Tract C-b. None were sighted during baseline studies, although recent diggings were observed in the lower section of Sorghum Gulch in a small Richardson's ground squirrel colony. Badgers were observed on several occasions within five miles of the Tract boundary.

3.4.3 Small Mammals

3.4.3.1 Rationale

Small mammals are important consumers of primary production and also serve as a prey base for many predators. Studies of small mammal community structure and population dynamics are, therefore, useful in monitoring changes in vegetative communities and in predicting changes in predator abundances and distributions. Concentration of pollutants by vegetation and other perturbations to plant communities and small mammals may be reflected by changes in small mammal population dynamics and physiological responses before larger and less common animals are affected.

Specific parameters of small mammal population dynamics were selected for study based upon the following considerations:

- Each parameter was measurable at a level of resolution which could be statistically evaluated and compared in future monitoring programs.

- Parameters were chosen that are commonly evaluated in other similar research and therefore could be compared to results from the literature.

- To satisfy conditions of the lease which stipulates that studies shall determine the species of fauna present, their distribution, their abundance, and plant/animal relationships.

3.4.3.2 Objectives

The objectives of small mammal studies were:

- To determine the species composition of the small mammal communities in major habitat types.
- To determine average live weights by species, sex, and age class.
- To describe seasonal reproductive activity and reproductive condition.
- To determine longevity and turnover rates for species present.
- To determine food habits for species on a seasonal basis.
- To determine average home range size.

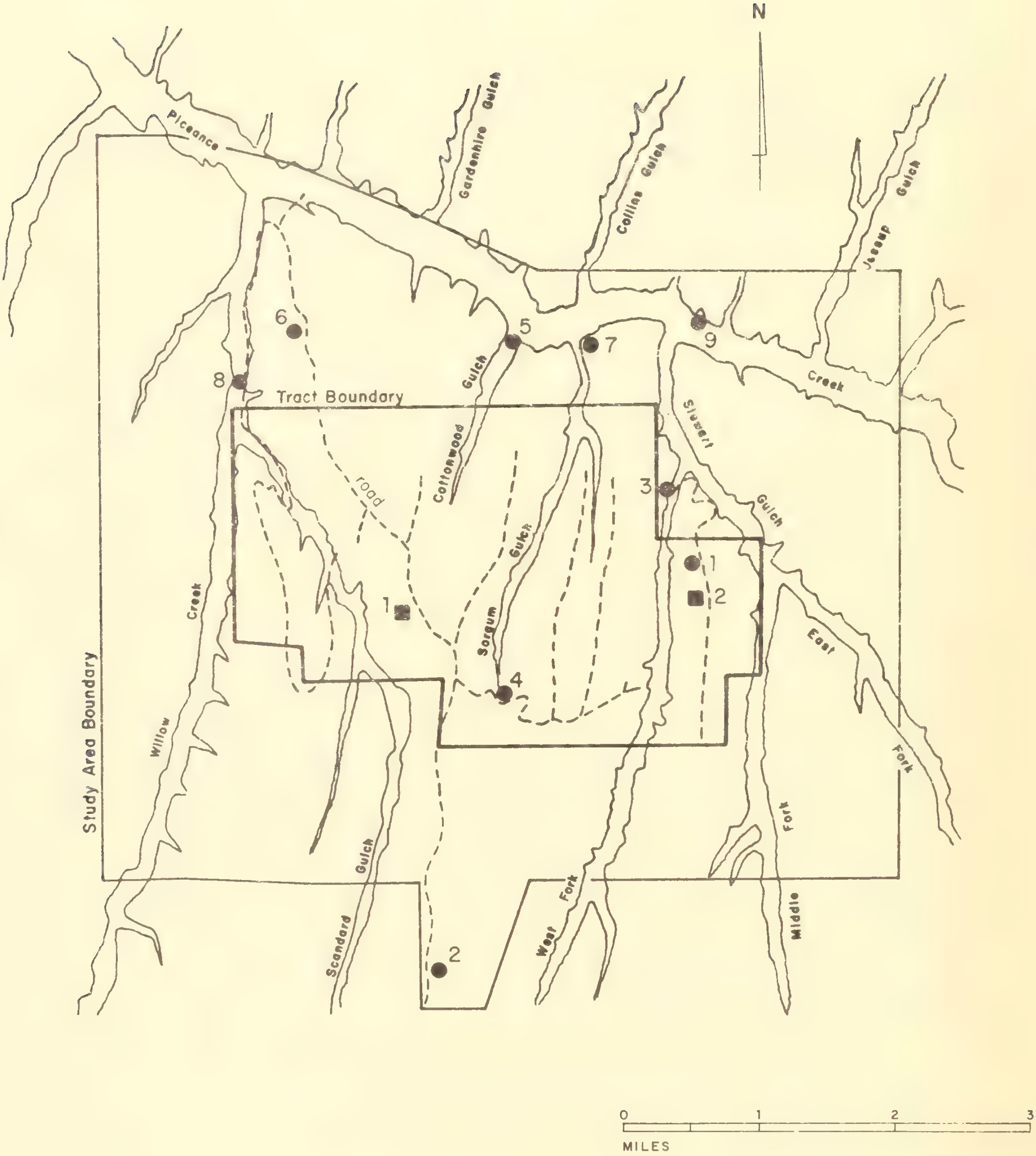
3.4.3.3 Experimental Design

Small mammal population parameters were sampled quantitatively at two grid locations (Figure 3-4-8) representing the major habitat types, chained pinyon-juniper rangeland and pinyon-juniper woodland, which comprise approximately 83 percent of the Tract C-b study area.

To obtain a complete inventory of small mammals, and to assess their relative abundance in all habitat types on Tract C-b, nine satellite grids were established (Figure 3-4-8) in vegetation and habitat types not represented by the two quantitative grids. Habitat types in which satellite grids were located included those characterized by a limited area, i.e., riparian and hay meadows; and important variations of the major habitat types, i.e., pinyon-juniper rimrock.

Analysis of food habits were conducted on animals captured in snap lines located near quantitative Grids 1 and 2. Snap lines consisted of 25 museum-special traps placed in a straight line.

Sampling was conducted during the months of May, June, July, August, and September at the two quantitative grids. This sampling schedule insured that small mammal populations were censused during their most active period, May-September, when the majority of reproduction and dispersal of subadults occurs. Satellite grids were sampled during the same months and, in



KEY:

● = Satellite small mammal trapping transect.

■ = Small mammal trapping grid

Figure 3-4-8

SMALL MAMMAL TRAPPING SITES

addition once during December-January. This sampling schedule provided relative abundance estimates and indices of reproductive conditon for small mammals during their most active period and also provided the same information for those small mammals which remain active throughout the fall and winter. Sampling was not conducted during winter months on the two quantitative grids due to the low number of active individuals and to avoid causing excessive trap deaths due to hypothermia.

3.4.3.4 Brief Methodological Description

Quantitative Grids 1 and 2 consisted of 100 Smith live traps placed on an inner grid and 52 Smith live traps placed on a dense line surrounding the inner grid (Figure 3-4-9). Trap spacing and grid design were modified from Smith et al. (1972) and Merino et al. (1974) (Appendix IV-A, Section A.4.2.1.1). Traps were baited with rolled oats and covered with plywood "A" frames to prevent excessive trap mortalities from inclement weather and heat stress.

All captured animals were individually marked by a sequence of toe clips or ear tags depending on the species (Appendix IV-A, Section A.4.2.1.1). Information recorded for each animal included species, sex, age class, reproductive condition, weight, identification number, and capture location. All weights were recorded with a Pesola spring scale.

The EM-2 stochastic model (Jorgensen et al. 1972) was used to calculate population estimates and ultimately the density of small mammals on Grids 1 and 2. This procedure can be applied to multiple capture-recapture data and partitions certain variables such as dispersal, mortality rates, and trap avoidance, thereby resulting in reliable estimates not easily obtained with other models (Appendix IV-A, Section A.4.2.1.1).

Satellite grids consisted of 24 to 50 Smith live traps. Traps were spaced 15 meters apart in various grid designs which were determined by terrain and vegetational restrictions. The general grid design consisted of a 4 x 6 array of traps. Animals caught in these traps were not generally marked, although limited marking of microtines on certain satellite grids was attempted. Information recorded for captured animals included sex, age class, and reproductive condition. Nomenclature used for small mammals collected from satellite grids as well as quantitative grids follows that of Armstrong (1972).

Home range size was calculated for the deer mouse and least chipmunk based on methods described by Calhoun and Casby (1958) (Appendix IV-A, Section A.4.2.1.5), which utilize the

NOTE: Area inside perimeter line = 2.72 hectares

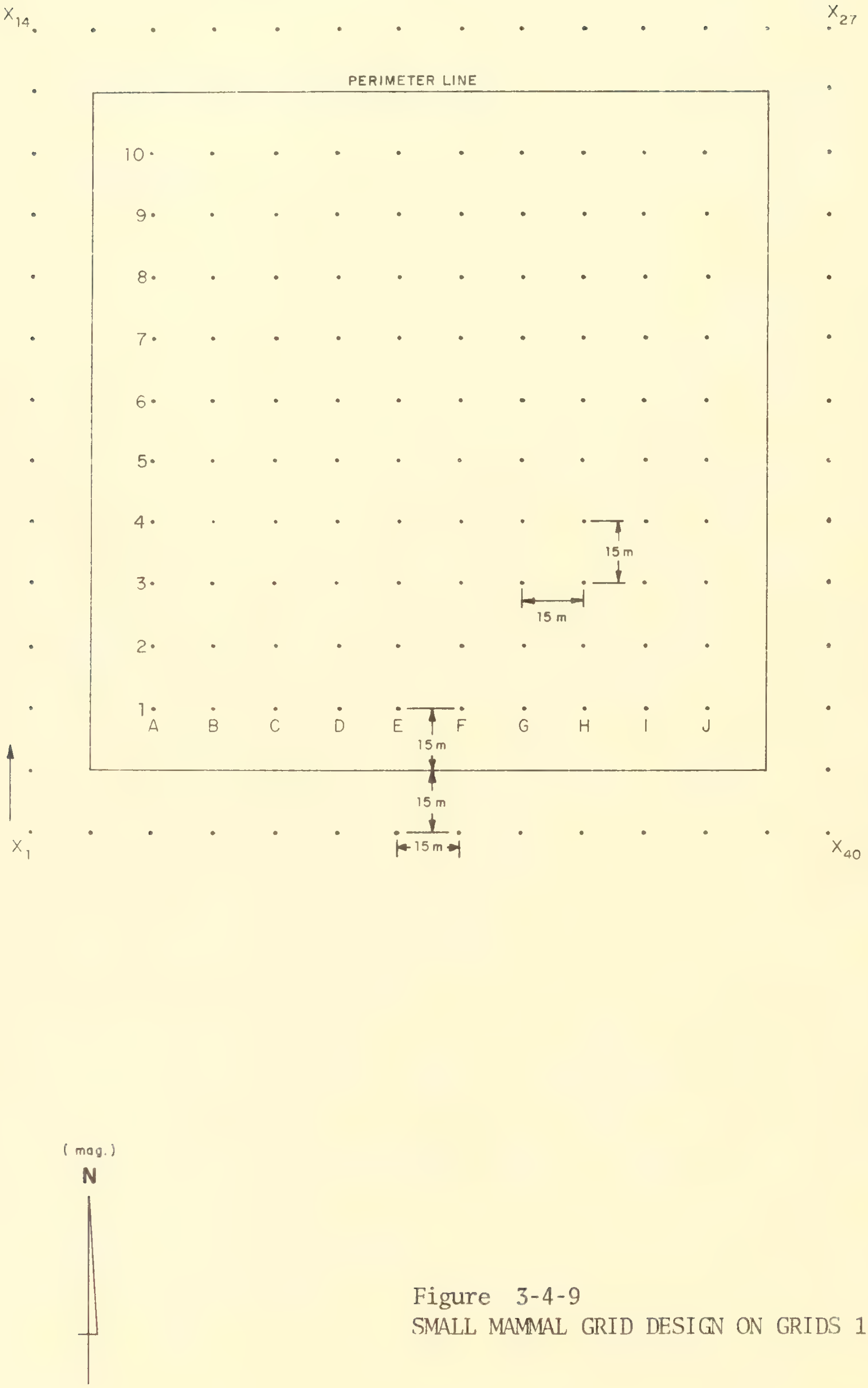


Figure 3-4-9
SMALL MAMMAL GRID DESIGN ON GRIDS 1 AND 2

standard deviation of the normal distribution function (sigma). Statistical comparisons utilizing the t-test were computed to determine any significant differences between sexes, age classes, species, and site.

Survivorship and turnover rates for the least chipmunk, Uinta chipmunk, and deer mouse were calculated for animals captured on Grids 1 and 2. The mark and recapture methodology used for density estimates was employed to compile a monthly recapture history of each marked animal. The length of time between the first capture and last capture was then computed for each animal. Minimum survivorship curves were plotted from these data. Mean survivorship was calculated after log transformation was performed on individual survivorship data (Appendix IV-A, Section A.4.2.1.6).

The relative frequency of diet items, number of embryos, and number of recent placental scars was determined for the least chipmunk and deer mouse (Appendix IV-A, Sections A.4.2.1.3 and A.4.2.1.7). Animals used in these laboratory studies were collected from snap lines located adjacent to Grids 1 and 2. The relative frequency of diet items was tested for significant differences between months and species.

3.4.3.5 Results and Discussion

3.4.3.5.1 Species Composition and Summary of Local Distribution of Small Mammals on Tract C-b

Sixteen species of small mammals were captured on quantitative and satellite grids (Table 3-4-8) during the baseline studies. Two additional species which are generally termed medium-sized mammals, the cottontail and long-tailed weasel, were also captured. Of this total, seven species were trapped in the pinyon-juniper woodland and 14 species were trapped in the chained pinyon-juniper. The remaining habitat types, i.e., agricultural meadows/riparian, pinyon-juniper rimrock, bottomland sagebrush, mixed mountain shrub, and bottomland sagebrush/rabbitbrush were represented by ten, four, eight, seven, and seven species, respectively.

A greater number of species were captured in the chained pinyon-juniper than in pinyon-juniper. This trend was apparent in every trapping period and has been reported in previous comparisons of small mammal diversity in pinyon-juniper and chained pinyon-juniper habitat (Turkowski and Reynolds 1970, Baker and Frischknecht 1975). The major factor contributing to the difference in small mammal diversity in both the earlier studies and in the present investigation, appeared to be habitat structure. In chained pinyon-juniper, downed trees bulldozed into slash

Table 3-4-8 SPECIES LIST AND LOCATION OF CAPTURE OR OBSERVATION OF SMALL MAMMALS ON TRACT C-b, AUGUST 1974 - AUGUST 1976

		Location on Tract										
		Permanent Grids		Satellite Grids								
		1	2	1	2	3	4	5	6	7	8	9
Soricidae												
Sorex cinereus	Masked shrew	X		X		X						
Sorex vagrans	Vagrant shrew	X										
Leporidae												
Sylvilagus audubonii	Cottontail	X	X			X						
Sciuridae												
Eutamias minimus	Least chipmunk	X	X	X	X	X	X	X	X	X	X	X
Eutamias umbrinus	Uinta chipmunk	X	X		X	X	X	X	X			X
Spermophilus lateralis	Golden-mantled ground squirrel	X	X	X	X	X		X	X	X	X	X
Spermophilus richardsonii	Richardson's ground squirrel						X					
Geomyidae												
Thomomys talpoides	Pocket gopher	X		X								
Heteromyidae												
Perognathus apache	Apache pocket mouse	X			X	X			X	X	X	
Cricetidae												
Lagurus curtatus	Sagebrush vole	X			X		X	X	X			
Microtus longicaudus	Long-tailed vole	X									X	
Microtus montanus	Montane vole	X	X	X	X	X	X	X	X		X	
Microtus pennsylvanicus	Meadow vole										X	
Neotoma cinerea	Bushy-tailed woodrat	X	X		X	X						
Peromyscus maniculatus	Deer Mouse	X	X	X	X	X	X	X	X	X	X	X
Peromyscus truei	Pinyon mouse	X										
Zapodidae												
Zapus princeps	Western jumping mouse			X								
Mustelidae												
Mustela frenata	Long-tailed weasel	X		X			X					

piles provided additional habitat for a variety of small mammals. In addition, an increase in diversity and abundance of herbaceous vegetation in the chained pinyon-juniper is created by removal of the pinyon and juniper overstory and resulted in new habitat and a greater abundance of food for small mammal species normally common in habitats with abundant herbaceous vegetation. Such species include voles, pocket gophers and shrews, which were not present on the pinyon-juniper grid but were often trapped near areas with abundant herbaceous vegetations on the chained pinyon-juniper grid.

Agricultural meadows/riparian, pinyon-juniper rimrock, bottomland sagebrush, and mixed mountain shrub habitat (sampled by satellite grids) were represented by fewer small mammal species than were present in chained pinyon-juniper. The general trend of fewer species in these secondary habitats may also be related to a lack of habitat structural diversity, e.g., low foliage height diversity. In addition, food resources which were less diverse in habitats such as bottomland sagebrush, may also have limited small mammal diversity. A limited number of food resources and a lack of habitat structural diversity often result in low species diversity (Hutchinson 1959).

The number of species present in the pinyon-juniper and secondary habitat types was similar, although there were important differences in the species composition between these habitat types. Habitat such as the riparian areas and agricultural meadows supported three species of voles, the pocket gopher, and only rarely species such as the chipmunks and ground squirrels which were more typically found in the pinyon-juniper. When species such as the chipmunk or ground squirrel were captured in agricultural meadows or riparian areas their presence was probably due to edge effect, i.e., the increase in number of species utilizing an ecotone or boundary between two different habitat types.

The distribution, or the range of habitats where a species was observed, varied widely with the species under consideration (Table 3-4-8). Several species that were observed in the study area appear to be specialists and occupy a limited number of habitats and others, such as the deer mouse, were widespread in their distribution.

3.4.3.5.1.1 Deer Mouse (Peromyscus maniculatus)

The deer mouse occurred in every habitat type within the study area (Table 3-4-8). In addition, burrows and other signs of activity were observed in a wide range of microhabitats such as trees, fallen trees, brush piles, and beneath shrubs.

3.4.3.5.1.2 Least Chipmunk (*Eutamias minimus*)

The least chipmunk was trapped regularly in every habitat other than agricultural meadows and riparian areas. In agricultural meadows and riparian areas, they were trapped only during the summer of 1976, when the population was at a peak and all available habitat was utilized. Because the agricultural meadows and riparian areas bordered habitat where chipmunks were extremely abundant, edge effect was also a factor which may have resulted in this distribution pattern. Burrows were observed under logs, bushes and rocks or outcroppings.

3.4.3.5.1.3 Uinta Chipmunk (*Eutamias umbrinus*)

In contrast to the least chipmunk, the Uinta chipmunk was limited in its distribution. The habitat where this species was most often captured consisted of xeric hillsides with abundant rimrock outcrops and scattered pinyon-juniper. Local distributions of the two chipmunk species apparently do not overlap and, although the Uinta chipmunk was captured in abundance on the same grid (Grid 2) as the least chipmunk, the two species were not captured at the same trap locations. Uinta chipmunk captures were restricted to hillside locations where rimrock outcroppings were predominant.

3.4.3.5.1.4 Montane Vole (*Microtus montanus*)

Montane voles were captured in agricultrual meadows/riparian habitat and in the herbaceous understory of chained pinyon-juniper. Voles rely on grasses and sedges for the majority of their diet and for cover to construct burrows and runways. As a result, habitats in the study area with limited grass cover did not support vole populations.

3.4.3.5.1.5 Golden-Mantled Ground Squirrel (*Spermophilus lateralis*)

This species occured in all habitat types on the Tract except for riparian areas and valley floor agricultural meadows. Although their distribution was widespread, specific habitat types supported the majority of individuals. These habitat types included rocky canyon slopes with pinyon-juniper and mixed mountain shrub, represented by Satellite Grid 5, and ridgetops with chained pinyon-juniper, represented by Grid 1 and Satellite Grid 3. This habitat preference agrees with that described by Lechleitner (1969) and McKeever (1964) who found this species occurring in rocky areas, meadows, or open coniferous forests. Apparently the preference for open areas is related to the larger amounts of herbaceous vegetation associated with an open canopy.

3.4.3.5.1.6 Apache Pocket Mouse (Perognathus apache)

The Apache pocket mouse was trapped with regularity on Grid 1 and Satellite Grids 7 and 8. The habitat of these locations was characterized by chained pinyon-juniper, sagebrush and agricultural meadows. In all areas where this species was captured, soil types were loose and sandy or sandy-loam. Apparently the preference for this particular soil type is related to the species' burrowing habit which results in a complex tunnel system at the base of rocks or plants (Lechleitner 1969, Olsen 1973).

The distribution of the Apache pocket mouse is restricted to the states of Utah, Colorado, New Mexico, and Arizona. In Colorado it has been observed along the drainages of the Colorado River in Garfield, Mesa, and Montrose Counties and in Mesa Verde National Park, Montezuma County (Lechleitner 1969). It has not previously been reported from Rio Blanco County.

3.4.3.5.1.7 Bushy-Tailed Woodrat (Neotoma cinerea)

Bushy-tailed woodrats normally select den sites in habitats which are rocky and/or shrubby (Lechleitner 1969). Often they are found in clefts on vertical cliffs or other outcrops of rocks. On Tract C-b den sites were most often observed in rimrock outcroppings with scattered pinyon-juniper and on chained pinyon-juniper sites where slash piles provided many den sites. No woodrats were trapped in valley agricultural meadows or in riparian areas.

3.4.3.5.2 Density Estimates and Trap Success on Quantitative Grids and Satellite Grids

3.4.3.5.2.1 Seasonal and Annual Fluctuations

Population estimates and trap success (Tables 3-4-9 and 3-4-10) show that important seasonal fluctuations in abundance occurred for small mammal species. For the majority of species the general pattern of seasonal fluctuations was low density in early spring, followed by an increase in number in summer, with maximum densities in

Table 3-4-9 DENSITY ESTIMATES (ANIMALS PER HECTARE) FOR SMALL MAMMALS ON GRIDS 1 (CHAINED PINYON-JUNIPER) AND 2 (PINYON-JUNIPER WOODLAND) AUGUST 1974 - AUGUST 1976

		Trapping Dates										
Scientific Name	Common Name	8/28-9/1 1974	9/18-9/22 1974	5/23-5/28 1975	6/26-6/29 1975	7/22-7/24 1975	8/26-8/28 1975	9/24-9/29 1975	5/21-5/27 1976	6/29-7/1 1976	7/27-7/29 1976	8/23-8/28 1976
GRID 1												
Sciuridae												
Eutamias minimus	Least chipmunk	4.5	9.4	13.2	1.7	1.8*	22.5	6.6	12.4	19.9	12.0	21.7
Eutamias umbrinus	Uinta chipmunk	---	---	0.4*	0	0	0	0	1.5*	1.5*	0.7*	0
Spermophilus lateralis	Golden mantled ground squirrel	0.4*	0	1.9	0.4*	2.9*	1.5*	0	3.8	1.1	0.6	0.3
Heteromyidae												
Perognathus apache	Apache pocket mouse	0	0	1.1	1.5	0	3.3	2.4	1.8*	1.3	0.7	0.4*
Cricetidae												
Microtus montanus	Montane vole	2.2	3.7*	0.4*	2.8	2.4	4.0*	2.2*	0.4*	0	0	1.8*
Peromyscus maniculatus	Deer mouse	7.0	19.1	3.9	3.6	6.5	11.1	12.5	11.1	6.2	17.1	20.9
GRID 2												
Sciuridae												
Eutamias minimus	Least chipmunk	1.4	5.2	2.4	1.8*	3.6	6.4	1.1*	13.5	9.9	18.3	25.0
Eutamias umbrinus	Uinta chipmunk	---	---	0	1.1	0	0.4*	1.5*	4.4*	4.3	8.6	6.3
Spermophilus lateralis	Golden-mantled ground squirrel	0.4*	0.7*	0	0	1.8*	1.1*	0	6.3	1.7	0.9	0.6
Cricetidae												
Peromyscus maniculatus	Deer mouse	12.1	28.4	2.2	2.3	2.2	8.2	2.4	22.8	17.1	19.2	23.6

* Number captured on grid when no density estimate is given by computer program due to insufficient recaptures.

Table 3-4-10

PERCENT TRAP SUCCESS FOR SMALL MAMMALS ON THE SATELLITE GRIDS, SEPTEMBER 1974 - AUGUST 1976

Scientific Name	Common Name	Grid[2]	Percent Trap Success[1] 9/74	11/74	1/75	5/75	6/75	7/75	8/75	9/75	11/75	1/76	3/76	4/76	6/76	7/76	8/76
Soricidae																	
Sorex spp.	Shrew	1										2					
		3		4								NS[3]	1				
Leporidae																	
Sylvilagus audubonii	Cottontail	3					2					NS	NS				
Sciuridae																	
Eutamias minimus	Least chipmunk	1													3	21	5
		2	8			17	17		15	17		NS	NS	40	28	36	46
		3	24			14	17	6	13	8		NS	NS	4	NS	NS	30
		4	20		NS	4				12		NS	NS	NS	20	36	40
		5	8		NS	18	8	2	15	12		NS	NS	25	NS	24	24
		6	16		NS	17	10	NS	25	8		NS	NS	20	26	28	40
		7			NS	21			4	11		NS	NS	NS	20	44	22
		8	NS		NS										5	20	23
		9	NS	NS	NS	3	4	2	6	2		NS	NS	NS	NS	NS	NS

Table 3-4-10 (continued)

Scientific Name	Common Name	Grid	Percent Trap Success 9/74	11/74	1/75	5/75	6/75	7/75	8/75	9/75	11/75	1/76	3/76	4/76	6/76	7/7C	8/76
Microtus longicaudus	Longtailed vole	8	NS		NS										1		
Microtus montanus	Montane vole	1	7	48	1		2	8	4	23		2	6	3	3	1	3
		3		4								NS	NS		NS	NS	
		4		1	NS			2	2	4		NS	NS	NS			
		5			NS			2				NS	NS		NS		
		6	16		NS				2			NS	NS				
		8	NS	40	NS							12			1	1	
Neotoma cinerea	Bushy-tailed woodrat	2						4				NS	NS				
		3							2			NS	NS		NS	NS	
Peromyscus maniculatus	Deer mouse	1	27	24	5	3	8	6	15	12	1			3	19	26	17
		2	60	35		11	6	17	29	29	17	NS	NS	20	16	4	2
		3	32	16		11	8	13	21	32	21	NS	NS	29	NS	NS	16
		4	44	65	NS	26		4	19	19		NS	NS	NS	8	12	1
		5	32	15	NS	4	10	25	33	19		NS	NS	17	NS	4	8
		6	28	13	NS	15	10	NS	29	42		NS	NS	20	6		4
		7	32		NS	18	17	35	42	33		NS	NS	NS			12
		8	NS		NS	17	29	35	46	43	3		8	35	19	15	18
		9	NS	NS	NS	15	6	13	48	20	4	NS	NS	NS	NS	NS	NS

Table 3-4-10 (continued)

Scientific Name	Common Name	Grid	Percent Trap Success 9/74	11/74	1/75	5/75	6/75	7/75	8/75	9/75	11/75	1/76	3/76	4/76	6/76	7/76	8/76
Eutamias umbrinus	Uinta chipmunk	2				8	2					NS	NS		8	4	4
		3										NS	NS		NS	NS	4
		4	4		NS							NS	NS				
		5			NS	3		6		4		NS	NS			8	4
		6			NS	1	2	NS		2		NS	NS				
		9	NS	NS	NS	3	2	2		2		NS	NS	NS	NS	NS	NS
Spermophilus lateralis	Golden-mantled ground squirrel	1														1	1
		2							2			NS	NS	20	4		4
		3				4	2	8	2	3		NS	NS	8	NS	NS	10
		5			NS	1	6	8				NS	NS		NS	4	8
		6			NS	3		NT				NS	NS		10	8	
		7			NS							NS	NS	NS	8		
		8	NS		NS										1	2	2
		9	NS	NS	NS	1			4			NS	NS	NS	NS	NS	NS

Table 3-4-10 (continued)

Scientific Name	Common Name	Grid	Percent Trap Success														
			9/74	11/74	1/75	5/75	6/75	7/75	8/75	9/75	11/75	1/76	3/76	4/76	6/76	7/76	8/76
Spermophilus richardsonii	Richardson's ground squirrel	4			NS	3	13				NS	NS	NS		16		
Geomyidae																	
Thomomys spp.	Pocket gopher	1				1											
Heteromyiidae •																	
Perognathus apache	Apache pocket mouse	2					2					NS	NS				
		3								3		NS	NS		NS	NS	
		6			NS	1		NS				NS	NS				
		7			NS		10		6	3		NS	NS	NS			
		8	N		NS			6	2	5							
Cricetidae																	
Lagurus curtatus	Sagebrush vole	2							2	4	4	NS	NS				
		4			NS				2			NS	NS	NS			
		5			NS				6	6		NS	NS		NS		
		6			NS			NS	2	4		NS	NS				

Table 3-4-10 (concluded)

Scientific Name	Common Name	Grid	Percent Trap Success 9/74	11/74	1/75	5/75	6/75	7/75	8/75	9/75	11/75	1/76	3/76	4/76	6/76	7/76	8/76
Zapodidae																	
Zapus princeps	Western jumping mouse	1					2		2	4					4	1	3
Mustelidae																	
Mustela frenata	Long-tailed weasel	1					2										1
		4			NS							NS	NS	NS			1

Footnotes:

[1] Percent trap success = $\frac{\text{No. of animals trapped}}{\text{trap nights}}$, where trap nights = (No. of traps)(No. of nights traps set); Less than 1% trap success = no entry
See Table 8-4-3 for complete list of trap nights for each grid.

[2] Location:
1) Piceance Creek - Riparian Vegetation/Agricultural Meadow
2) West Stuart Creek - Bottomland Sagebrush
3) Tract Entrance Road - Chained Pinyon-Juniper Rangeland
4) Lower Sorgum Gulch - Bottomland Sagebrush/Rabbitbrush
5) Middle Sorgum Gulch - Pinyon-Juniper Woodland
6) Upper Sorgum Gulch - Mixed Mountain Shrub
7) Lower Cottonwood Gulch - Bottomland Sagebrush
8) Willow Creek - Riparian Vegetation/Agricultural Meadow
9) Grid 2 Satellite - Pinyon-Juniper Woodland

[3] NS = Not Sampled

late summer-early fall. This general trend resulted from a combination of winter mortalities, spring reproductive effort, and later summer dispersal of subadults from spring litters.

Annual fluctuations were also apparent from population estimates and trap success (Tables 3-4-9 and 3-4-10). Generally, these fluctuations are attributed to either density-dependent factors, i.e., behavioral interactions which determine the incidence and duration of sexual activity, number of young weaned per successful pregnancy and the survival of subadults, or to food resources that vary from year to year (Chew and Turner 1974). High densities recorded in the summer and fall of 1976 for the majority of small mammal species represented in Grids 1 and 2 were most likely related to abundant food resources rather than density-dependent factors. Due to mild weather and an abundant food supply during April-June, a majority of juveniles from spring litters survived and dispersed as subadults into the population (Appendix IV-B, Figures B-4-1 through B-4-4).

The magnitude of such annual fluctuations and the general pattern of seasonal fluctuations varied by species and are discussed below for each major small mammal species on Tract C-b.

3.4.3.5.2.1.1 Deer Mouse

Deer mice were abundant in every habitat on Tract C-b and represented one of the two most abundant species on Tract C-b. Seasonal fluctuations followed the general trend of increased numbers in early summer, due to litter production, and maximum densities in late summer when the majority of subadults dispersed (Table 3-4-9).

Maximum densities occurred in September 1974, August 1975, and again in August 1976. The timing of these peak densities was most directly related to weather conditions and primary production in early spring which determined the initiation of breeding activity and ultimately the month of maximum dispersal of subadults in late summer. Although the months of maximum density were apparent for the deer mouse, density estimates sometimes fluctuated throughout the summer months, exhibiting several smaller peaks in density (Table 3-4-9). Two factors were most responsible for these fluctuations: (1) the adverse effects of weather on the accuracy of small mammal population estimates (Olsen 1973) and (2) females are polyestrous and may have several litters during the breeding season, resulting in several peaks in density during each breeding season.

Deer mice populations on Grids 1 and 2 fluctuated by factors of 1.7 and 1.9 from September 1974 to August 1975, and by factors of 2.9 and 3.5 from August 1975 to August 1976. This magnitude of annual fluctuations in density is relatively small compared to those observed in many other small mammals such as vole species (Terman 1965), and is comparable to the average annual fluctuation of 2.2 reported by Terman (1968) for deer mice from 18 different populations. Low magnitudes of annual population fluctuations suggest that deer mice may be relatively sensitive to factors controlling population growth and thus their growth is limited within a narrower numerical range of variability than is true for more widely fluctuating species (Terman 1965). Mechanisms which may act to control population growth include high mortality of young, cessation of reproduction by adult females, and inhibition of reproduction in the majority of the females born into the population (Terman 1965).

3.4.3.5.2.1.2 Least Chipmunk

The least chipmunk was abundant in every habitat type with the exception of riparian areas and agricultural meadows. Their density on Grids 1 and 2, and trap success on satellites, was similar to that recorded for the deer mouse (Tables 3-4-9 and 3-4-10). Seasonal fluctuations followed the general trend of increasing numbers in early summer and maximum densities in late summer when subadults dispersed (Table 3-4-9). Maximum densities occurred in the same months that deer mice densities peaked, i.e., September 1974, August 1975, and August 1976. Although a seasonal peak in density was apparent, densities fluctuated somewhat throughout the breeding season due to the adverse effects of weather on the small mammal population estimates. However, the fluctuations in density were less severe than fluctuations in the deer mouse population because the least chipmunk does not produce multiple litters and as a result exhibit only one definite density peak in each breeding season.

Least chipmunk populations on Grids 1 and 2 fluctuated by factors of 1.1 and 1.2 between September 1974 and August 1975 and by factors of 2.4 and 4.0 between August 1975 and August 1976. The magnitude of these annual fluctuations is similar to that recorded for deer mice and may suggest that this species is also relatively sensitive to density dependent factors which control population growth.

Although the magnitude of annual fluctuations was similar to deer mice, the length of time between maximum and minimum population levels varied from that of the deer mouse. The maximum and minimum densities for deer mice occurred during one year periods, i.e., September 1974-August 1975, August 1975-August 1976, while least chipmunk populations remained low on Grid 2 until the end of the second year of trapping. The reasons for this two year low for least chipmunks on Grid 2 were not apparent during the baseline studies.

3.4.3.5.2.1.3 Uinta Chipmunk

The Uinta chipmunk was most abundant on Grid 2 and Satellite Grids 5, 6, and 9 (Tables 3-4-9 and 3-4-10). Very few were captured on Grid 1 due to a lack of preferred habitat, i.e., scattered pinyon-juniper and rimrock.

Seasonal fluctuations were similar to those discussed for the least chipmunk. There was a single peak in densities that occurred in July-August. A single litter per breeding season which was produced in May-June was responsible for this late summer density peak.

The highest densities recorded during baseline studies occurred during the late summer of 1976 on Grid 2 (Table 3-4-9). Apparently mild weather and abundant food supply in early spring were responsible for this density increase as discussed for the least chipmunk. Densities during July and August of 1976 were 40-60 times greater than those recorded in 1975. This magnitude of annual fluctuations is much larger than that recorded for the least chipmunk. This may indicate that the Uinta chipmunk has a high potential for population fluctuations over short periods. However, because the species is relatively rare (Table 3-4-9), insufficient recaptures make population estimates relatively unreliable and as a result, population fluctuations between years may be due to sampling problems as well as other causes.

3.4.3.5.2.1.4 Montane Vole (*Microtus montanus*), Long-Tailed Vole (*Microtus longicaudus*), and Sagebrush Vole (*Lagurus curtatus*)

A relatively low number of voles were captured during baseline studies. Of the three species that were trapped only the montane vole was captured often enough to evaluate seasonal and annual fluctuations in density. Montane vole densities ranged from 1.0 - 6.0 per hectare on Grid 1 and trap success on Satellites 1 and 8 ranged from 0 percent - 48 percent. Peak densities were recorded on Grid 1 in September 1974 and August 1975. Trap success on Satellite Grids 1 and 8 was highest during November-December 1974.

The months of peak densities, August-November, indicate that vole populations in this geographic area are highest during late summer and fall. Although montane voles breed throughout the warmer months, and produce several litters per season (Lechleitner 1969), apparently the months of maximum litter production and subadult dispersion on Tract C-b are August-December. Similar seasonal fluctuations, i.e., late fall peak densities, have been documented for the montane vole in previous studies (Hoffman 1958).

The population of adult voles entering the breeding season in April-June of each year was difficult to assess during the present studies. Relatively few voles were captured during this period and virtually no recaptures were recorded. The EM-2 estimator does not produce an estimate when no recaptures are recorded. However, the actual number of adults in the population during the early part of the breeding season was estimated to be higher than trap results indicated. Although microtines are reported to have a relatively high reproductive potential (Golley 1961), a spring-summer population larger than that observed on Tract C-b would have been required to result in the population levels observed in the fall.

The lack of trapping success during spring and summer months on Tract C-b may be related to low seasonal bait response. Herbaceous vegetation, the preferred diet of voles, is normally abundant and high in protein content during spring and summer months in this geographic area. As a result, vole populations may not have been attracted to a less preferred diet item such as rolled oats until the late summer-fall season when herbaceous vegetation declines in quantity and quality.

In contrast to the deer mouse and least chipmunk, the montane vole exhibited very large annual fluctuations in density. The fluctuations were most apparent on Satellite Grids 1 and 8, i.e., agricultural meadows and riparian areas which were preferred by the montane vole, where trap success was 48 percent and 40 percent in November-December of 1974. At these same locations trap success declined to 23 percent and 0 percent in the fall of 1975 and 3 percent and 0 percent in the fall of 1976. Widely fluctuating vole populations with periodic "crashes," such as the population low in 1975-1976 on Tract C-b, are well documented in the literature (Hoffman 1958, Terman 1966, and Lechleitner 1969).

These population lows may be the result of increased mortality of juveniles which suffer a breakdown in the adreno-pituitary system when subjected to stress in high-density populations (Hoffman 1958). How important this factor may be on Tract C-b is not clear. It is suggested, however, that predation by raptors over the winter may also have been important in reducing vole numbers. Analysis of raptor pellets collected during fall, winter, and spring of 1974 - 1975 indicated that many raptors fed extensively on the montane vole during this period.

3.4.3.5.2.1.5 Golden-Mantled Ground Squirrel

The golden-mantled ground squirrel was the fourth most abundant small mammal on quantitative Grids 1 and 2 and the satellite grids during the majority of trapping periods. Their abundance was greatest in pinyon-juniper and chained pinyon-juniper and lowest in agricultural meadows and riparian areas.

Densities were highest during the period May-July in 1975 and 1976 (Table 3-4-9). Late spring-early summer density peaks for the golden-mantled ground squirrel were due primarily to subadults from early spring litters. This species breeds once per year during early spring, approximately two to three weeks after arousal from hibernation, and produces two to eight young per litter. Juveniles become active above ground approximately 40 days after birth (McKeever 1964).

Hibernation by the golden-mantled ground squirrel is an adaption to a combination of low temperatures and restricted food, and therefore is initiated in the fall when these conditions become established (McKeever 1964). Related species, such as Spermophilus mohavensis and Spermophilus beldingi become dormant in late July or early August (McKeever 1964) because of seasonally restricted food. In contrast, a diversified diet permits the golden-mantled ground squirrel to be active through the late summer months until frozen ground and cold temperatures initiate hibernation.

A significant decline in densities occurred during the period August-October in 1974, 1975, and 1976 (Table 3-4-9). This decline was apparently not due to the initiation of hibernation since mild temperatures and adequate food supplies persisted throughout this period. An alternate explanation for this decline is that subadults which were very active in early summer became less active in late summer due to their assimilation into the population or dispersion into areas outside the grids. Density estimates can be affected by activity rates and are often underestimated or are characterized by large confidence intervals when activity is low.

Annual fluctuations of density estimates were in the range of 1.3 - 3.5 on Grids 1 and 2 from 1975 to 1976. The largest densities occurred in the summer of 1976 when most other small mammal species were also numerous.

3.4.3.5.2.1.6 Miscellaneous Species

Many species were not trapped often enough to assess seasonal or annual fluctuations. Several are important members of the small mammal community and serve as important prey species.

Sorex cinereus and *Sorex vagrans* (the masked shrew and vagrant shrew) and *Thomomys talpoides* (the northern pocket gopher) may have been more numerous than was indicated by live trapping (Tables 3-4-9 and 3-4-10). Since shrews feed primarily on animal matter (insects and worms) and gophers feed primarily on forbs and grasses, neither species was attracted to live traps baited with rolled oats. The large number of northern pocket gophers which was consumed by raptors during spring and early summer months indicates that this species was at least seasonally abundant in certain habitats. It is expected that the majority of gophers on Tract C-b inhabit agricultural meadows and bottomland sagebrush areas.

The Apache pocket mouse (*Perognathus apache*), the sagebrush vole (*Lagurus curtatus*), Richardson's ground squirrel (*Spermophilus richardsonii*), and the western jumping mouse (*Zapus princeps*) were rarely captured due primarily to the limited extent of their preferred habitat on Tract C-b. Specialized habitat types which are preferred by these species, i.e., sagebrush vole - sagebrush stands, Apache pocket mouse - sparse vegetation and loose, sandy soils, Richardson's ground squirrel - grassy meadows, western jumping mouse - moist areas with lush vegetation, are not well represented on Tract C-b and as a result the numbers of these four species are also restricted. In the case of the Apache pocket mouse, low densities would have been expected even if preferred habitat had been available. Lechleitner (1969) reports that the species is never very abundant in Colorado and most observations have been of single or several individuals.

Densities of bushy-tailed woodrat (*Neotoma cinerea*) averaged 1.0 - 1.5 animals per hectare during the 1974 and 1975 breeding seasons (Table 3-4-9). In 1976 density estimates declined to 0 on both grids. This decline in density was apparently not a normal occurrence since the bushy-tailed woodrat is not subject to the severe annual fluctuations that have been discussed for vole populations. The factor most responsible for this decline may have been a high number of trap deaths in 1974 and 1975. The bushy-tailed woodrat experienced trap death throughout the study period when nighttime temperatures fell below 45° - 50°F. Although this range of temperature was not lethal for many other species that survive cold temperatures because of body size and behavioral and physiological adaptations, the bushy-tailed woodrat apparently could not survive in this range of temperature when held overnight in the traps. Previous studies have indicated that periods of hypothermia are not always dependent on ambient temperature and may occur at temperatures well above 32.0° F (Ingels 1965). A significant number of trap deaths which could not be balanced by high immigration rates or successful reproductive efforts apparently reduced the woodrat population in 1976.

3.4.3.5.2.2 Comparison of Small Mammal Populations on Grids 1 and 2

Chaining operations were conducted on Tract C-b in 1966, approximately eight years before the initiation of baseline studies in August of 1974. Small mammal trapping results show there was no significant difference in the total number of individuals which were marked in chained areas (represented by Grid 1) and in areas left unchained (Grid 2) during the period August 1974-August 1976 (Table 3-4-11). Similar results have been obtained in previous studies of the response of small mammals on recently chained pinyon-juniper range (Baker and Frischknecht 1973). In those studies an initial decrease in the total number of individuals was observed one year after chaining; an increase was noted after two years; and finally the total number of individuals on treated and untreated plots stabilized and showed no significant difference after four years.

Although there was no significant difference in the number of total individuals, important differences in the abundance of certain species were noted on Grids 1 and 2.

The total number of marked deer mice on Grid 1 was greater (542) than least chipmunks (256) and showed higher densities during seven of the eleven trapping periods from 1974-1976 (Tables 3-4-9 and 3-4-11). In the remaining four trapping periods densities of the two species did not differ appreciably or were characterized by large confidence intervals which made comparisons unreliable.

The total number of marked least chipmunks was greater on Grid 1 (405) than on Grid 2 (256) and showed higher densities in six of eleven trapping periods. Densities did not differ appreciably in the remaining trapping periods or were characterized by large confidence intervals which make comparisons unreliable. Due to the greater number of least chipmunks on Grid 1 the total number of marked least chipmunks (408) was comparable to the total number of deer mice (453) on Grid 1. In terms of the number of animals, this resulted in codominant species on Grid 1 (the least chipmunk and deer mouse) while the deer mouse represented the dominant species in Grid 2.

Table 3-4-11 TOTAL NUMBER OF MARKED ANIMALS ON GRIDS 1 (CHAINED PINYON-JUNIPER RANGELAND) AND 2 (PINYON-JUNIPER WOODLAND) [INCLUDING DENSE LINES] WITH CHI-SQUARE TESTS FOR GOODNESS OF FIT BETWEEN GRIDS FOR THE PERIOD AUGUST 1974 - AUGUST 1976

Species Scientific Name	Common Name	Number (Grid 1)	Number (Grid 2)	Calculated X^2 [1]
SCIURIDAE				
Eutamias minimus	Least chipmunk	408	256	34.75[1]
Eutamias umbrinus	Uinta chipmunk	18	102	57.41[1]
Spermophilus lateralis	Golden-mantled ground squirrel	94	67	4.20[1]
HETEROMYIDAE				
Perognathus apache	Apache pocket mouse	37	0	35.03[1]
CRICETIDAE				
Microtus montanus	Montane vole	82	2	76.00[1]
Neotoma cinerea	Bushy-tailed woodrat	21	13	1.83
Peromyscus Maniculatus	Deer mouse	453	582	15.83[1]
	TOTAL	1113	1022	3.79

[1] Significant difference at $\alpha = .05$.

Differences in habitat structure are a factor which appears to affect density of small mammal species as well as species composition (M'Closkey 1975). The presence of significant heterogeneity in the herb-shrub layer of chained pinyon-juniper i.e., habitat characterized by mixed patches of shrubs and herbs, and an increase in edge effect due to chaining may have led to the establishment of the deer mouse and least chipmunk as codominant species. Less diversity in habitat structure within the herb-shrub layer of the pinyon-juniper and less edge effect apparently resulted in higher densities of the deer mouse on Grid 2. These species are therefore termed complementary in habitat requirements with least chipmunk densities increasing and deer mice densities decreasing as the herb-shrub layer becomes more heterogeneous and edge effect is produced within a chained pinyon-juniper area. Other small rodents are known to respond in a complementary manner to similar changes in herbaceous ground cover (Turkowski and Reynolds 1970).

It is unlikely that a difference in density of the deer mouse and least chipmunk on Grids 1 and 2 was due to a competition for food resources which may have varied between the two sites. Deer mice are generalized in their diet and are insectivorous, while the least chipmunk consumed more vegetation and seeds.

Two species which were not as numerous as the deer mouse and least chipmunk, the Colorado chipmunk and montane vole, also varied in abundance between the two grids. The total number of marked Colorado chipmunks was much higher on Grid 2 (102) than on Grid 1 (18) and the number of marked montane voles was greater on Grid 1 (82) than on Grid 2 (2). A greater abundance of herbaceous vegetation, the preferred diet item of montane voles, on the chained plot (Grid 1) was most responsible for an increase in vole densities. The presence of rimrock and sandstone outcroppings was responsible for higher Colorado chipmunk densities on Grid 2.

3.4.3.5.3 Reproduction

3.4.3.5.3.1 Deer Mouse

3.4.3.5.3.1.1 Timing of Reproductive Activity

Deer mouse reproductive activity generally commences in the spring and continues with varying intensity through the summer. Females are polyestrous, have a postpartum heat, and may have several litters per breeding season (Lechleitner 1969).

The initiation of reproductive activity in the study area for the 1975 breeding season occurred in May when 85 percent to 90 percent of the males and 30 percent to 60 percent of the females were reproductive on Grids 1 and 2 (Figures 3-4-10 and 3-4-11). It is typical for males to show a peak in reproductive activity before females in order that females, especially those which come into estrus early, are insured of impregnation.

During the period June-August 1975 the percentage of reproductive females fluctuated somewhat but remained relatively high, i.e., 60 percent to 90 percent, throughout the period, indicating that many females produced in the early spring litters became reproductive in late summer and added to the total of reproductive females present in August. The impregnation of subadult females is not abnormal and has been reported for other small mammal species (O'Farrell et al. 1975).

Peak female reproductive activity (95 percent), and lower male reproductive activity (45 percent) in May on Grids 1 and 2 indicated that the 1976 breeding season had been initiated prior to the first trapping period (Figures 3-4-10 and 3-4-11). Based upon the general pattern of reproductive activity established in 1975, the initiation of reproductive activity for males apparently occurred at least one to two months earlier than in 1975.

Length of day, quantity and quality of vegetation, and temperature regimes are all factors which have been correlated to the initiation and success of the breeding season for various species (Ingles 1965). The cue for early initiation of breeding activity in 1976 may have been correlated to abundant vegetation which resulted from favorable temperatures and above average precipitation in April and May. The initiation and success of reproductive activity due to abundant green vegetation has been documented by Beatly (1969), Reichman and Van De Graaff (1975), and Chew and Butterworth (1964). According to these studies large quantities of green vegetation may provide physiological signals that there is sufficient moisture for lactation by females and a large seed crop for the imminent expanding population, or estrogenic substances in the developing plants may stimulate females into estrus and stimulate development of the good body condition necessary for reproduction.

The rapid decline in the percentage of reproductive males and females during the period June-August 1976 indicates that most female deer mice did not produce second litters and that many subadult females were not reproductive in late summer, as they had been in 1975. The absence of a sustained breeding season may have been related to density-dependent factors, i.e., social interactions due to high density levels, or to a lack of

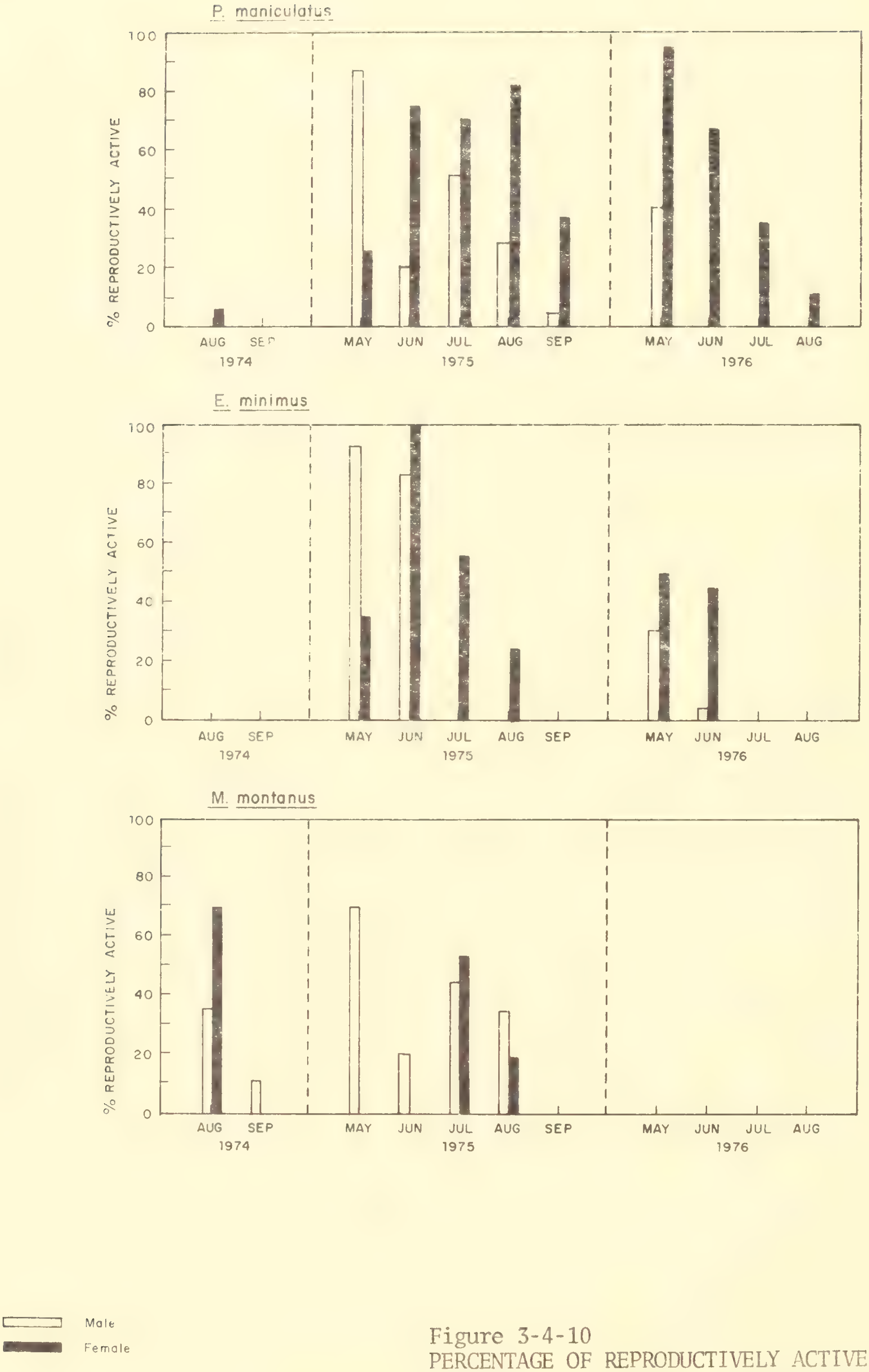


Figure 3-4-10
PERCENTAGE OF REPRODUCTIVELY ACTIVE PEROMYSCUS MANICULATUS, EUTAMIAS MINIMUS, AND MICROTUS MONTANUS ON GRID 1 (CHAINED PINYON-JUNIPER RANGELAND).

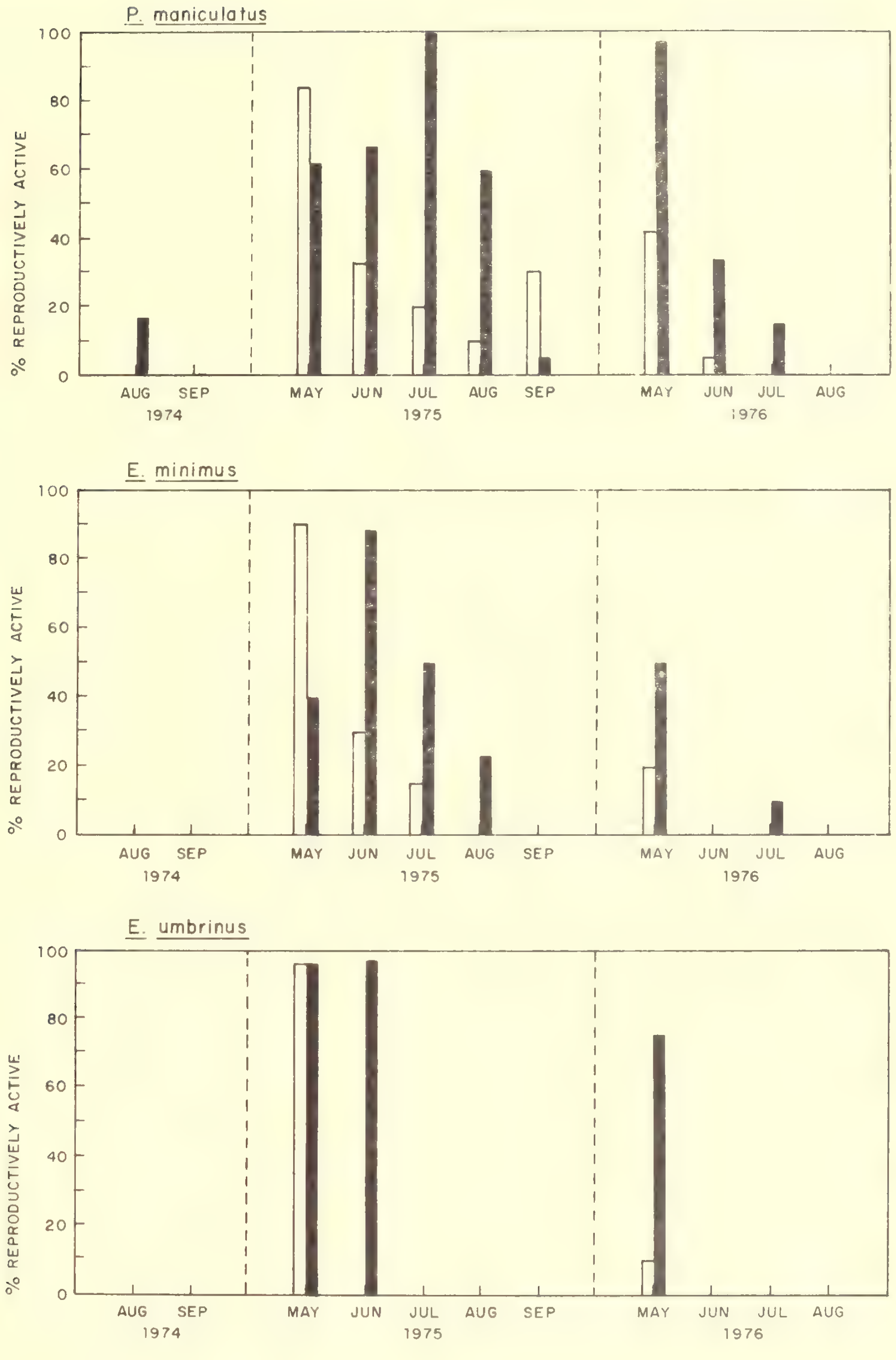


Figure 3-4-11
PERCENTAGE OF REPRODUCTIVELY ACTIVE PEROMYSCUS MANICULATUS, EUTAMIAS MINIMUS, AND EUTAMIAS UMBRINUS ON GRID 2 (PINYON-JUNIPER WOODLAND).

good quality green vegetation and seeds in the June-August period. A freeze in mid-June damaged many shrubs and grasses and presumably lowered seed production in the late summer.

3.4.3.5.3.1.2 Reproductive Condition/Mean Number of Embryos and Placental Scars

The mean number of embryos produced by reproductive females, the number of litters produced, and the number of young which survive and disperse from each litter are all important parameters which determine the reproductive potential of small mammal species. These parameters may be influenced by quantity and quality of food resources (Reichman and Van De Graaff 1974) and density-dependent factors (Hoffman 1958) which affect juvenile mortality rates through a breakdown of the adreno-pituitary system in stressed individuals.

The mean number of embryos per deer mouse on Grids 1 and 2 was 5.0 and 5.2, respectively (Appendix IV-B, Table B-4-4). These means are very similar to the mode of 5.0 embryos per female deer mouse given by Lechleitner (1969).

The mean number of recent placental scars, i.e., scars produced in the 1975 reproductive season, was 12.0 and 10.5 on Grids 1 and 2, respectively (Appendix IV-B, Table B-4-4). Given a mean number of 5.0 embryos per reproductive female, approximately two litters were produced by each reproductive female in the population during the 1975 reproductive season.

For many small mammal species the survival rate between implantation of the embryo and the time of actual trapping is 50 percent (Turner and McBrayor 1974). Based upon a mean number of 5.0 embryos per reproductive female and approximately a 90 percent fertility rate for the adult female population (Figures 3-4-10 and 3-4-11), the ratio of subadults recruited into the population to adult females should have been approximately 2.5 during months of maximum subadult dispersal. Density estimates for months of maximum subadult dispersal, i.e., September 1974, August 1975, May 1976, showed a subadult to adult female ratio of .90-1.5. These ratios were much lower than would be expected if 50 percent of the young from each litter survived and 100 percent of the subadults which dispersed had an equal probability of being trapped. Either behavioral interactions between adults and subadults, i.e., dominance and territorial behavior exhibited by adults and dispersal activity, prevented substantial numbers of subadults from entering traps or the survival rate of juveniles was lower than 50 percent. A long-term decline or rise in baseline subadult/adult female ratio would indicate a change in the survival rate of juveniles since the chance of trapping subadults would not be expected to change unless trapping methods were altered.

3.4.3.5.3.2 Least Chipmunk

3.4.3.5.3.2.1 Timing of Reproductive Activity

This species generally breeds in late spring and early summer, with females producing one litter per season. Females normally produce litters of four to six animals which begin to forage for themselves before the end of summer (Lechleitner 1969).

The initiation of breeding activity for the 1975 season occurred in May when 90 percent of the males and 35 percent to 40 percent of the females were reproductive on Grids 1 and 2 (Figures 3-4-10 and 3-4-11). This pattern is similar to that discussed for the deer mouse. Peak female reproductive activity, 90 percent to 100 percent, occurred one month later, then declined rapidly during the period July-September. The absence of a second peak or sustained rate of reproductive activity in this period indicates that this species produced one litter in 1975.

Peak female reproductive activity, 95 percent to 100 percent, and lower male reproductive activity, 40 percent, in May 1976 indicated that the 1976 breeding season had been initiated prior to the first trapping period (Figures 3-4-10 and 3-4-11), as observed for the deer mouse population. Early initiation of breeding activity, similar to the early initiation of breeding activity for the deer mouse, was probably correlated to the availability of abundant vegetation in this period. During the period June-August reproductive activity declined, indicating that, as in 1975, one litter was produced during the 1976 reproductive season.

3.4.3.5.3.2.2 Reproductive Condition/Mean Number of Embryos and Placental Scars

The mean number of embryos produced per least chipmunk on Grids 1 and 2 was 5.5 and 5.1, respectively (Appendix IV-B, Table B-4-4). Previous studies have reported average litter sizes of four to six young (Lechleitner 1969).

The mean number of recent placental scars, i.e., scars produced in the 1975 reproductive season, was 5.8 and 5.4 on Grids 1 and 2 (Appendix IV-B, Table B-4-4). Given a mean number of 5.3 embryos per reproductive female, it is clear that only one litter was produced in the 1975 reproductive season. One litter per year for the least chipmunk has been documented in several previous studies (Lechleitner 1969).

Based upon a mean number of 5.3 embryos per reproductive female and approximately a 90 percent - 100 percent fertility rate for the adult female population, the ratio of subadults recruited into the trappable population to adult females should have been 2.5 if the juvenile survival rate approached 50 percent. Density estimates for months of maximum subadult dispersal, i.e., September 1974, August 1975, and June 1975, showed a subadult to adult female ratio of 0.5-1.3. These ratios were much lower than would have been expected if 50 percent of the young from each litter survived and 100 percent of the subadults which dispersed had an equal probability of being trapped. Possible explanations for the lower than expected ratio are similar to those discussed for the deer mouse: behavioral interactions between adults and subadults which prevent capture of subadults, dispersal out of the grid by subadults before they are captured, or a lower than 50 percent survival rate by juveniles.

3.4.3.5.3.3 Montane Vole

3.4.3.5.3.3.1 Timing of Reproductive Activity

Montane voles breed during the warmer months of the year in Colorado. Females are polyestrous and have a postpartum heat and several litters of from one to eight young per season. Normally, first litters are smallest and succeeding litters are larger. The gestation period is approximately 21 days. Females and males may breed in the season they are born (Lechleitner 1969).

Due to the limited number of montane voles captured on Grid 1 during 1974-1975 and the cyclic population low which reduced the population to very low numbers in 1976, information collected on reproductive activity and timing was minimal (Figure 3-4-10). However, the data do show that montane voles in 1974 and 1975 remained reproductive throughout the fall season and that the percentage of reproductive females was highest in the period August-October. This pattern varied substantially from the other species studied, which show peak reproductive activity in early spring and summer with a decline in late summer and fall.

3.4.3.5.3.4 Uinta Chipmunk

3.4.3.5.3.4.1 Timing of Reproductive Activity

The reproductive season, number of young per litter, and number of litters per year for the Uinta chipmunk are reported to be similar to the least chipmunk (Lechleitner 1969). Due to the relatively few numbers of Uinta chipmunks captured on Grid 2 any deviations from this general description of reproductive habits were difficult to discern. However, it was noted that like the least chipmunk, peak reproductive activity was highest during the spring (Figure 3-4-11) and declined significantly later in the summer. This indicated that only one litter was produced and that initiation of reproductive activity may have been correlated with quantity and quality of vegetation as was discussed for the least chipmunk and deer mouse.

3.4.3.5.4 Live Weights

3.4.3.5.4.1 Deer Mouse

Average live weights recorded in the spring, May 1975 and 1976, were higher than average live weights recorded in the late summer-early fall, September 1975 and August 1976 on Grids 1 and 2 for both males and females (Table 3-4-12). Generally the summer season affords the most favorable conditions for growth in terms of photoperiod, temperature, and primary productivity (Smith et al. 1974) for this year-round active species. Therefore, it is likely that low average live weights in late summer are not due to a decline in general condition but are the result of large numbers of subadults which entered the population prior to live weight determinations. If these animals were trapped shortly after their independent foraging was initiated, their genetic limits for growth probably had not yet been met (Smith et al. 1974) and the average live weight per animal would necessarily be lowered. Animals which had initiated independent foraging and were reproductively active in August and September were considered adults and included in the adult live weight category even though the majority had been classified as subadults in June and July.

3.4.3.5.4.2 Least Chipmunk and Uinta Chipmunk

Live weights recorded in the spring, May 1975 and 1976, were similar to live weights recorded in late summer-early fall, September 1975 and August 1976, on Grids 1 and 2 for both males and females (Tables 3-4-13 and 3-4-14). This indicates that unlike the deer mouse, juvenile and subadult live weights merge quickly into the weight class of the previous generation.

Table 3-4-12 LIVE WEIGHTS OF PEROMYSCUS MANICULATUS ON TRACT C-b, SEPTEMBER 1974 - AUGUST 1976

	Chained Pinyon-Juniper (Grid 1)				Pinyon-Juniper Woodland (Grid 2)			
Class	5/75	9/75	5/76	8/76	5/75	9/75	5/76	8/76
ADULT MALES								
Number weighed	9	8	6	22	11	17	8	23
Mean weight (gm.)	21.7	15.5	17.3	15.3	21.7	14.3	18.0	12.7
Range	17.0-	11.0-	12.0-	12.0-	18.0-	9.5-	15.0-	12.0-
	27.0	21.0	21.0	19.0	25.0	21.0	21.0	17.0
Standard deviation	4.0	3.9	3.6	2.0	2.3	3.4	2.0	1.8
Confidence interval (95%)	X̄±3.1	X̄±3.4	X̄±1.5	X̄±0.9	X̄±1.5	X̄±1.7	X̄±1.7	X̄±0.8
SUBADULT MALES								
Number weighed	0	0	3	1	0	0	8	0
Mean weight (gm.)	---	---	13.3	11.0	---	---	12.6	---
Range	---	---	13.0-	---	---	---	7.0-	---
	---	---	14.0	---	---	---	16.0	---
Standard deviation	---	---	0.6	---	---	---	3.2	---
Confidence interval (95%)	---	---	X̄±0.9	---	---	---	X̄±0.9	---
ADULT FEMALES (non-reproductive)								
Number weighed	16	6	0	11	3	11	1	30
Mean weight (gm.)	20.2	14.5	---	16.9	19.0	13.5	20.0	13.7
Range	15.5-	12.0-	---	12.0-	17.0-	9.0-	---	10.0-
	26.5	21.0	---	22.0	22.0	20.0	---	27.0
Standard deviation	3.5	3.6	---	3.6	2.6	3.1	---	3.7
Confidence interval (95%)	X̄±1.9	X̄±3.8	---	X̄±2.4	X̄±6.5	X̄±2.1	---	X̄±1.4
ADULT FEMALES (reproductive)								
Number weighed	3	5	7	3	8	1	12	0
Mean weight (gm.)	24.7	19.4	23.1	18.0	21.3	21.0	21.3	---
Range	23.0-	14.0-	17.0-	13.0-	18.5-	---	17.0-	---
	27.5	29.0	25.0	24.0	25.0	---	26.0	---
Standard deviation	2.5	5.8	4.2	5.6	2.4	---	2.9	---
Confidence interval (95%)	X̄±6.2	X̄±7.2	X̄±1.5	X̄±13.8	X̄±2.0	---	X̄±1.8	---
SUBADULT FEMALES								
Number weighed	0	0	1*	0	0	0	7	0
Mean weight (gm.)	---	---	21	---	---	---	12.3	---
Range	---	---	---	---	---	---	9.0-	---
	---	---	---	---	---	---	19.0	---
Standard deviation	---	---	---	---	---	---	3.6	---
Confidence interval (95%)	---	---	---	---	---	---	X̄±3.3	---

* reproductive subadult

Table 3-4-13 LIVE WEIGHTS OF EUTAMIAS MINIMUS ON TRACT C-b, SEPTEMBER 1974 - AUGUST 1976

	Chained Pinyon-Juniper (Grid 1)				Pinyon Juniper Woodland (Grid 2)			
	5/75	9/75	5/76	8/75	5/75	9/75	5/76	8/76
ADULT MALES								
Number weighed	36	16	12	14	11	1	16	9
Mean weight (gm.)	32.9	32.7	31.0	30.7	31.5	24.0	35.3	32.2
Range	28.0-	30.0-	29.0-	26.0-	29.0-	---	28.0-	27.0-
	44.5	36.0	34.0	34.0	34.0	---	43.0	35.0
Standard deviation	4.3	1.9	1.8	2.0	1.9	---	4.6	2.5
Confidence interval (95%)	X̄±1.5	X̄±1.0	X̄±1.1	X̄±1.2	X̄±1.3	---	X̄±2.3	X̄±1.9
SUBADULT MALES								
Number weighed	0	0	0	0	0	0	4	0
Mean weight (gm.)	---	---	---	---	---	---	26.0	---
Range	---	---	---	---	---	---	17.0-	---
	---	---	---	---	---	---	33.0	---
Standard deviation	---	---	---	---	---	---	7.1	---
Confidence interval (95%)	---	---	---	---	---	---	X̄±11.3	---
ADULT FEMALES (non-reproductive)								
Number weighed	30	5	4	12	7	1	0	12
Mean weight	33.7	33.6	32.8	32.6	36.6	50.0	---	32.1
Range	21.5-	30.0-	29.0-	20.0-	32.0-	---	---	26.0-
	40.0	37.0	36.0	41.0	41.0	---	---	36.0
Standard deviation	3.8	2.5	3.3	5.7	3.2	---	---	2.9
Confidence interval (95%)	X̄±1.4	X̄±3.1	X̄±5.3	X̄±3.6	X̄±3.0	---	---	X̄±1.8
ADULT FEMALES (reproductive)								
Number weighed	20	0	4	0	5	0	3	0
Mean weight (gm.)	41.9	---	41.3	---	34.2	---	36.3	---
Range	26.5-	---	39.0-	---	30.5-	---	29.0	---
	53.0	---	44.0	---	39.5	---	41.0	---
Standard deviation	6.8	---	2.1	---	3.1	---	6.4	---
Confidence interval (95%)	X̄±3.2	---	X̄±3.3	---	X̄±3.8	---	X̄±15.9	---
SUBADULT FEMALES								
Number weighed	0	0	0	1	0	0	3	0
Mean weight (gm.)	---	---	---	10.0	---	---	29.7	---
Range	---	---	---	---	---	---	22.0-	---
	---	---	---	---	---	---	38.0	---
Standard deviation	---	---	---	---	---	---	8.0	---
Confidence interval (95%)	---	---	---	---	---	---	X̄±19.9	---

Table 3-4-14 LIVE WEIGHTS OF *EUTAMIAS UMBRINUS* ON TRACT C-b, SEPTEMBER 1974 - AUGUST 1976

Class	Pinyon-Juniper Woodland Grid 5/75	 9/75	 5/ 76	 8/76
ADULT MALES				
Number weighed	7	1	9	11
Mean weight (gm.)	52.4	50.0	45.3	47.3
Range	43.0- 58.0	--- ---	28.0- 56.0	40.0- 52.0
Standard deviation	5.1	---	8.7	3.7
Confidence interval (95%)	X̄±4.7	---	X̄±6.7	X̄±2.5
SUBADULT MALES				
Number weighed	0	0	0	0
Mean weight (gm.)	---	---	---	---
Range	--- ---	--- ---	--- ---	--- ---
Standard deviation	---	---	---	---
Confidence interval (95%)	---	---	---	---
ADULT FEMALES (non-reproductive)				
Number weighed	0	0	1	4
Mean weight (gm.)	---	---	41	51.8
Range	--- ---	--- ---	--- ---	45.0- 55.0
Standard deviation	---	---	---	4.6
Confidence interval (95%)	---	---	---	X̄±7.3
ADULT FEMALES (reproductive)				
Number weighed	6	0	6	0
Mean weight (gm.)	59.7	---	46.0	---
Range	56.0- 65.0	--- ---	42.0- 53.0	--- ---
Standard deviation	3.1	---	4.4	---
Confidence interval (95%)	X̄±3.3	---	X̄±4.6	---
SUBADULT FEMALES				
Number weighed	0	0	0	0
Mean Weight (gm.)	---	---	---	---
Range	--- ---	--- ---	--- ---	--- ---
Standard deviation	---	---	---	---
Confidence interval (95%)	---	---	---	---

Average live weights for the same age class and same sex did not vary appreciably between years for the least chipmunk, Uinta chipmunk or the deer mouse (Tables 3-4-12, 3-4-13, and 3-4-14). This may indicate that average live weights are more conservative and less subject to annual fluctuations than other parameters such as density estimates. For this reason a long-term decrease in the average live weight for these species could serve as a reliable measure of deterioration in habitat quality resulting in reduced food supplies.

3.4.3.5.5 Home Ranges

Home range size was computed for 74 individual least chipmunks and deer mice which met established criteria for home range calculations (Table 3-4-15). Home ranges were computed separately for adult males, adult females, subadult males, and subadult females since home range size can vary by sex and age class (Maza et al. 1973). Data used for these calculations was collected during August and September of 1974 and May-August of 1975. Therefore the home range sizes which were calculated represent average values for the months when reproductive activity was highest (May-June) and for the months of subadult dispersal (July-September).

On Grid 1 the range of sigma (1 standard deviation from the mean = to the radius of a hypothetical circle of its activity) was 17.0 m - 47.7 m for the least chipmunk. The mean home range in hectares was 1.17 ha for males and 0.94 ha for females. The range in sigma for the deer mouse at this site was 10.0 m - 31.1 m. The mean home range was 0.67 ha for deer mouse males and 0.56 ha for females.

In the pinyon-juniper woodland (Grid 2) least chipmunk sigma values ranged from 15.2 m to 37.8 m. The mean home range for males was 1.40 ha and for females 0.95 ha. Deer mouse sigma values ranged from 10.6 m to 38.7 m while mean home ranges for the sexes ranged from 0.61 ha to 1.19 ha.

A comparisons test was used to determine if significant differences in sigma values existed between age classes on each grid (Appendix IV-B, Table B-4-5). On Grid 1 no significant differences were found. On Grid 2 deer mouse subadult females had a significantly larger home range than adult females. Insufficient captures of subadult animals prevented home range calculations for the least chipmunk on Grids 1 and 2 and for the deer mouse on Grid 2. It is expected that larger home range size of subadults would have been substantiated with additional captures. Subadults generally exhibit larger home range size as a result of dispersal activity.

Table 3-4-15 HOME RANGE (2 Sigma) VALUES FOR LEAST CHIPMUNKS AND DEER MICE ON THE CHAINED PINYON-JUNIPER GRID AND THE PINYON-JUNIPER WOODLAND GRID

Site/Species	N	Total Captures	Home Range (ha)
Chained Pinyon-Juniper			
Eutamias minimus			
Males	14	93	1.17
Females	11	106	0.95
Peromyscus maniculatus			
Adult Males	4	24	0.67
Subadult Males	3	22	0.49
Females	12	101	0.56
Pinyon-Juniper Woodland			
Eutamias minimus			
Males	3	16	1.40
Females	7	58	0.95
Peromyscus maniculatus			
Males	11	88	0.61
Adult Females	7	61	0.70
Subadult Females	2	15	1.19

Although the home ranges of adult male least chipmunks and deer mice on Grids 1 and 2 were larger than female home ranges, the difference was not statistically significant (Appendix IV-B, Table B-4-5). If additional recapture of adults had been possible during reproductive months (May-June) this difference may have been significant at the .05 level. Generally, adult males have a larger home range during the months when reproductive activity is most intense (Maza et al. 1973).

Comparison tests also showed no significant differences in the home range size between grids for either species (Appendix IV-B, Table B-4-5). The least chipmunk had home range sizes which were significantly larger than the deer mouse on both grids.

Home ranges may be modified according to the availability of resources, i.e., food resources, nesting sites, and cover (Connell 1954), or as a result of behavioral interactions related to density-dependent factors (Maza et al. 1973). For example, enlargement of the home range during periods of population decline may be due to changes in social interaction or it may reflect changes in quality of the environment and availability of resources. An increase in foraging distances or home range size which occurs may therefore indicate a deterioration in habitat quality or may be a result of normal population cycle declines.

3.4.3.5.6 Survivorship and Turnover Rate of Marked Animals on Grids 1 and 2

Although several factors may have contributed to an underestimate of survivorship, i.e., dispersal, unknown age structure, and lack of trapping data for winter months, the resulting survivorship curves (Figure 3-4-12) and mean survivorship (Table 4-16) were in good agreement with documented survivorship for various other small mammal species (Chew and Butterworth 1974, Olsen 1973, French et al. 1967).

To allow an analysis of survivorship, species must be relatively abundant, easily recaptured, and not overly susceptible to trap-induced mortality. Three species on Grids 1 and 2 met these criteria: the deer mouse, least chipmunk, and the Uinta chipmunk.

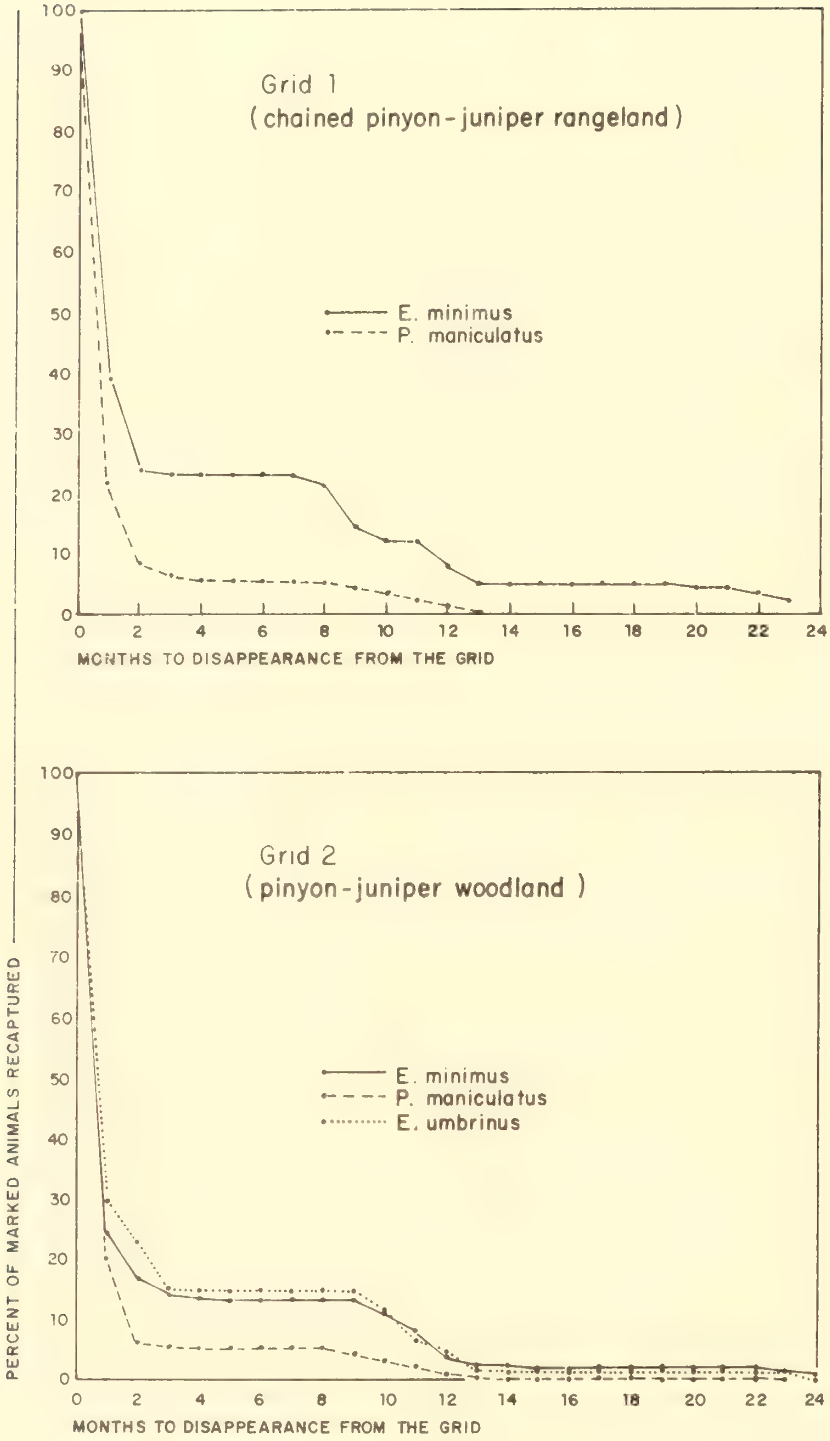


Figure 3-4-12
PERSISTENCE (SURVIVORSHIP) OF MARKED ANIMALS ON GRIDS 1 AND 2

Table 3-4-16 MEAN SURVIVORSHIP[1] (MOS.) FOR SMALL MAMMALS ON GRIDS 1 AND 2, AUGUST 1974 - AUGUST 1976

	Mean Survivorship ± S.E. (N)	
Species	Chained Pinyon-Juniper	Pinyon-Juniper Woodland
SCIURIDAE		
Eutamias minimus	1.9 ± 1.1 (253)	1.5 ± 1.1 (196)
Eutamias umbrinus	---	1.6 ± 1.1 (61)
HETEROMYIDAE		
Perognathus apache	1.5 ± 1.2 (23)	---
CRICETIDAE		
Microtus montanus	1.2 ± 1.1 (59)	---
Peromyscus maniculatus	1.3 ± 1.0 (330)	1.3 ± 1.0 (416)

[1] See text for an explanation of mean survivorship as it applies to these data.

3.4.3.5.6.1 Deer Mouse

The deer mouse was the least persistent species on Grids 1 and 2. Seventy-seven to eighty percent of all animals captured were not recaptured after one month and 92-95 percent were not captured after two months. Mean survivorship was 1.3 months (Table 3-4-16). Data from a previous study (Olsen 1973) indicates that the median age of 9,000 deer mice captured over a five year period was three to four months. From these data it is apparent that the longevity of deer mice on Tract C-b is generally less than six months and that high turnover rates are common.

Based upon a three-four month average life span it was expected that the majority of deer mice on Grids 1 and 2 from any given reproductive season would not persist in the population throughout winter months. This was substantiated by recapture data which showed only 4 percent - 5 percent of animals marked in a given reproductive season were present on Grids 1 and 2 following the winter months (Figure 3-4-12).

Deer mice are active throughout the winter in the study area, are preyed upon by a variety of predators, are susceptible to a number of diseases, and have many parasites such as ticks, fleas, and botflies (Lechleitner 1969). All of these factors may contribute to high turnover and poor survivorship for the deer mouse.

3.4.3.5.6.2 Least Chipmunk

The least chipmunk showed a higher persistence than the deer mouse on Grids 1 and 2. Twenty-five to forty percent were recaptured after one month and 17 percent - 24 percent were present after two months (Figure 3-4-12). Mean survivorship was 1.5 months on Grid 2 and 1.9 months on Grid 1 (Table 3-4-16). Thirteen to fifteen percent were recaptured after nine months indicating that turnover rate was lower and overwinter survival was much higher than rates discussed for the deer mouse.

Although least chipmunks do not hibernate, they remain in burrows for extended periods during cold weather and rely on food stored during the growing season (Lechleitner 1969). Inactivity during winter months may have enhanced the persistence of least chipmunks by decreasing their exposure to predators and unfavorable weather. Similar findings are reported for other species which hibernate or remain inactive during winter months (Chew and Butterworth 1974).

3.4.3.5.6.3 Uinta Chipmunk

The persistence and turnover rate of the Uinta chipmunk were very similar to that discussed for the least chipmunk (Figure 3-4-12). Mean survivorship was 1.6 months (Table 3-4-16). Information regarding the habits and ecological requirements of this species is lacking. But based upon its relatively low turnover rate it is likely that the Uinta chipmunk remains inactive for extended periods during the winter; this is similar to the behavior described for the least chipmunk.

3.4.3.5.7 Food Habits

3.4.3.5.7.1 Deer Mouse

The deer mouse is known to consume a wide variety of plants, arthropods, and seeds, and to be highly opportunistic in the selection of diet items (Johnson 1962, Douglas 1969). Analysis of food habits during the period May-September 1975 showed seasonal shifts in the relative frequency of diet items consumed, which was correlated with the seasonal availability of those diet items (Table 3-4-17). On Grids 1 and 2 a significantly greater abundance of arthropods was consumed than green plant material throughout the spring and early summer when arthropod populations were very abundant (Appendix IV-B, Table B-4-6). In August and September the relative frequency of green plant material consumed increased as arthropod populations decreased or were no longer available as diet items. Lepidopterous larvae, which were the most frequently consumed arthropods, were only available as diet items before metamorphosis and were therefore unavailable as a diet item after early summer. The relative frequency of seeds consumed increased in September, due to seed production which occurred during this period.

A change in the relative frequency of diet items consumed was observed in the 1976 sampling period (Table 3-4-17). Green vegetation was consumed more frequently than arthropods during June and July on both grids. This may have been due to a decrease in the availability of the arthropods consumed by deer mice or to an abundance of green vegetation in these months. Since mild weather and above average precipitation occurred during the early months of 1976, abundant vegetation was apparently most responsible for the increase in vegetation consumed. Subsequently, a freeze occurred in mid-June which damaged shrubs and grasses and also adversely affected the 1976 seed crop. As a result, the relative frequency of seeds consumed in late summer was very low, the frequency of vegetation items consumed decreased, and deer mice relied primarily on arthropods as an alternate food source (Table 3-4-17).

Table 3-4-17 RELATIVE FREQUENCIES OF SMALL MAMMAL DIET ITEMS, MAY 1975 - AUGUST 1976

	Peromyscus maniculatus				*Eutamias minimus*			
	Stomachs Examined	Vegetation %	Arthropods %	Seeds %	Stomachs Examined	Vegetation %	Arthropods %	Seeds %
Grid 1								
Chained Pinyon-Juniper								
May 1975	6	19.2	79.1	1.7	3	50.7	48.6	0.7
June 1975	3	31.7	68.3	0.0	1	67.9	32.1	0.0
July 1975	3	32.2	67.8	0.0	3	63.9	29.6	6.5
August 1975	3	47.2	50.9	1.9	7	56.9	33.9	9.2
September 1975	1	49.0	0.0	51.0	3	38.3	0.0	61.7
June 1976	1	59.0	41.0	0.0	7	58.2	38.1	3.7
July 1976	6	69.1	30.6	0.3	9	66.5	32.5	1.0
August 1976	8	49.2	50.8	0.0	9	67.3	31.0	1.7
Grid 2								
Pinyon-Juniper Woodland								
May 1975	4	22.2	75.9	1.9	2	66.2	33.8	0.0
June 1975	4	21.2	78.8	0.0	1	61.1	38.9	0.0
July 1975	6	51.6	44.4	4.0	0	---	---	---
August 1975	4	39.4	60.6	0.0	6	60.6	21.6	17.8
September 1975	1	50.0	0.0	50.0	0	---	---	---
June 1976	2	80.0	19.2	0.8	4	78.0	15.7	6.3
July 1976	3	54.5	45.1	0.4	5	59.3	33.3	7.4
August 1976	10	34.6	66.0	0.0	3	74.2	21.8	4.0

3.4.3.5.7.2 Least Chipmunk

The least chipmunk, like the deer mouse, is an opportunistic feeder and will consume vegetation, arthropods, and seeds (Johnson 1962). However, there were some differences between relative frequencies of diet items consumed by the least chipmunk and the deer mouse in 1975 and 1976. Vegetation was the diet item most frequently consumed throughout the growing season (May-September) in both 1975 and 1976. This indicates that the least chipmunk continues to consume vegetation more often than arthropods during periods when green vegetation is not as abundant and has declined in forage quality, i.e., during July-September 1976 following the freeze.

The increased intake of seeds by least chipmunks during late summer 1975, when seeds were abundant, was similar to the increase in consumption of seeds by the deer mouse. However, in 1976 the consumption of seeds by the least chipmunk during late summer was appreciably higher than the consumption of seeds by the deer mouse even though seed production was low. This difference may be related to the least chipmunk habit of storing seeds for consumption during extended cold periods. The least chipmunk may expend considerable energy foraging for seeds even when their availability is low because it does not actually hibernate and depends on winter reserves for survival.

3.4.4 Birds

3.4.4.1 Rationale

3.4.4.1.1 Census Measures

Section 1, Paragraph C(2d) of the Oil Shale Environmental Lease Stipulations, requires that over a two-year period the Lessee must study the avifauna of the leased land and of lands lying within one mile of the leased lands. The purposes of these studies are to determine the spatial and temporal distribution and abundance of birds within the specified area. The Stipulations further indicate that "migratory patterns of birds" are to be determined.

3.4.4.1.2 Habitat Requirements of Principal Species

The Stipulations also indicate that key relationships between the avian community of other components of the Tract C-b ecosystems should be identified. To accomplish this, "important species" are emphasized herein, as a means of conveniently illustrating ecological dependencies of avian community components on dominant Tract habitats. Restricting the discussion to important species is done because it is neither feasible nor worthwhile to discuss habitat requirements and ecological interrelationships of all of the more than 135 birds species that appear in the study area from time to time.

To some extent, importance reflects a human value judgment which is not easily quantified and which may be made in several contexts. According to guidelines of one federal agency, for example, the importance of a species may be a function of its recreational value, its economic influences in relation to agriculture, its status as a rare or endangered species, its aesthetic qualities (all four of which reflect a culturally-derived view of the species), its role in the energy or nutrient processes of ecosystems, or its function in controlling the dynamics of other populations (both of which reflect biologically determined values). In some cases, these guidelines are more appropriately applied to a broader taxon or category than that of a single species. Because there is seldom a sharp demarcation where species or groups no longer meet the criteria of "importance," the discussions must necessarily be to some extent arbitrarily exclusive.

3.4.4.2 Objectives

3.4.4.2.1 Census Measures

The objectives of the avian census program are to satisfy the lease requirements by identifying the bird species that occur within the study area on a seasonal and annual basis, and to determine for principal species their abundance in and use of dominant habitats.

3.4.4.2.2 Habitat Requirements of Principal Species

The objectives of the avian baseline program also include developing an objective designation for important species and the habitat requirements of these species as they relate to Tract C-b environs.

3.4.4.3 Experimental Design

To develop information on the kinds, abundances, and habitat requirements of birds utilizing Tract habitats during different seasons, a number of experimental designs were employed to determine presence and numbers of songbirds, upland gamebirds, waterfowl, and raptors. A brief description of the experimental design is presented here.

3.4.4.3.1 Experimental Design - Census Measures

3.4.4.3.1.1 Quantitative Songbird Censuses

Quantitative censuses of songbirds and certain nonsongbirds residing in or utilizing major vegetation types on Tract C-b and adjacent land were conducted during 11 sampling periods from October 1974 to July 1976. Ten habitats were censused for species composition and abundance according to the schedule specified in Table 3-4-18. Descriptions of sampled habitats are given in Table 3-4-19, and their locations are depicted on Pocket Figure 3-4-13 (refer to pocket, inside back cover).

During each of the first seven sampling periods, Transects 1-4, 5A, 6, 7A, and 8 were censused a single time. However, based on analyzed results of these censuses, after completion of the first year of censusing, the intensity of sampling and some original transect locations were adjusted as appropriate to improve data interpretability and usefulness. The "Upland Sagebrush Vegetation Plot" transect (Transect 7A) was eliminated because its size was inadequate for meaningful censusing. This stand was not large enough to allow for an 800 m linear transect, nor could upland sagebrush stands of sufficiently large coverage for effective censusing be located within the study area. A stand of upland transition habitat (Transect 7B) of mixed pinyon-juniper and sagebrush was selected as an alternate site (Pocket Figure 3-4-13), and was censused in February, April, and late May 1976. This habitat type has a much greater coverage and distribution in the study area than does upland habitat dominated by big sagebrush alone, and therefore is more suitable for sampling the avian communities representative of the Tract C-b area.

The Middle Sorghum Gulch transect (Transect 5A) was eliminated because it did not conform to the requirement of general uniformity of physiography and vegetation for stands used in this type of quantitative censusing (Emlen 1971). Transect 5A followed a rocky drainage bottom and then traversed a fairly steep slope of sparse pinyon-juniper woodland. This transect was replaced with one that traverses a west-facing slope of relatively homogeneous pinyon-juniper woodland (Transect 5B). The locations of these transects are depicted on Pocket Figure 3-4-13.

The four principal habitat types on Tract C-b and adjacent areas are the pinyon-juniper woodland, chained pinyon-juniper woodland, bottomland sagebrush, and riparian meadow communities bordering creeks. Because these four habitats support the majority of bird species and bird numbers, the sampling effort on transects traversing them was increased during the second year of censusing. Transects 1, 2, 3, 4, and 5B were each sampled three times on consecutive days and at similar times during the eighth, ninth, and tenth censusing periods. Censusing the five transects in triplicate

Table 3-4-18 SCHEDULE OF BASELINE DATA COLLECTION ON BIRDS AT TRACT C-b

Census Period	Strip Transect Number										Night Owl Transects	Waterfowl Counts	Raptor Nest Survey	Pellet Cast Collections
	1	2	3	4	5A	5B	6	7A	7B	8				
October 1974	$\surd^1$	$\surd^1$	$\surd^1$	$\surd^1$	$\surd^1$		$\surd^1$	$\surd^1$		$\surd^1$		✓	✓	
November 1974	$\surd^1$	$\surd^1$	$\surd^1$	$\surd^1$							✓	✓		
January 1975	$\surd^1$	$\surd^1$	$\surd^1$	$\surd^1$	$\surd^1$		$\surd^1$	$\surd^1$		$\surd^1$		✓		
March 1975	$\surd^1$	$\surd^1$	$\surd^1$	$\surd^1$								✓		✓
May 1975	$\surd^1$	$\surd^1$	$\surd^1$	$\surd^1$	$\surd^1$		$\surd^1$	$\surd^1$		$\surd^1$	✓	✓	✓	✓
July 1975	$\surd^1$	$\surd^1$	$\surd^1$	$\surd^1$								✓		
September 1975	$\surd^1$	$\surd^1$	$\surd^1$	$\surd^1$	$\surd^1$		$\surd^1$	$\surd^1$		$\surd^1$		✓		
October 1975														✓
December 1975											✓		✓	✓
February 1976	$\surd^3$	$\surd^3$	$\surd^3$	$\surd^3$		$\surd^3$	$\surd^1$		$\surd^1$	$\surd^1$		✓		✓
April 1976	$\surd^3$	$\surd^3$	$\surd^3$	$\surd^3$		$\surd^3$	$\surd^1$		$\surd^1$	$\surd^1$		✓		✓
May 1976											✓	✓	✓	
June 1976	$\surd^3$	$\surd^3$	$\surd^3$	$\surd^3$		$\surd^3$	$\surd^1$		$\surd^1$	$\surd^1$				
July 1976	$\surd^1$	$\surd^1$	$\surd^1$	$\surd^1$								✓		✓

$\surd^1$ = transect sampled once during census period
$\surd^3$ = transect sampled in triplicate during census period

Table 3-4-19 CHARACTERIZATION OF STRIP TRANSECTS SAMPLED FOR BIRDS ON TRACT C-b

Transect 1 (Mammal Plot No. 10). This transect includes chained pinyon-juniper woodland habitat. The vegetation includes a heterogeneous mixture of immature pinyon pine, serviceberry, Gambel's oak, sagebrush, and bitterbrush. A large number of snags provide specialized habitats for certain birds.

Transect 2 (Oldland Ranch - Piceance Creek). Bordered by agricultural meadow, this transect traverses along Piceance Creek west to east. Several small stands of Douglas fir and mixed mountain shrub border the southeast corner of the plot.

Transect 3 (West Fork Stewart Gulch). Bordered to the east and west by sharply rising slopes, this north-south transect traverses through a dense, heterogeneous stand of sagebrush and rabbitbrush. The eroded sandstone slopes support a sparse growth of pinyon-juniper. The habitat is classified as bottomland sagebrush.

Transect 4 (Mammal Plot No. 17). This transect route through a pinyon-juniper woodland includes a single habitat type. The trees are primarily mature pinyon pine and juniper with a sparse understory of mountain shrub.

Transect 5A (Middle Sorghum Gulch). This plot consists of a mature but sparse stand of pinyon-juniper. Big sagebrush, Gambel oak, and serviceberry comprise the thin understory.

Transect 5B (Pinyon-juniper Woodland). Bordered to the east by large tracts of chained pinyon-juniper woodland this transect traverses an undisturbed stand of mature pinyon-juniper having a sparse understory of mixed mountain shrub.

Transect 6 (Collins Gulch). The strip transect runs south to north on the west slope of Collins Gulch; this strip is bordered on the west by sandstone banks which maintain a sparse covering of pinyon-juniper and mixed mountain shrub. A north-south highway forms the east boundary of the strip.

Transect 7A (Upland Sagebrush Vegetation Plot). This strip transect traverses through upland sagebrush and bunch grass. The extreme south boundary borders a sparse stand of immature pinyon-juniper.

Transect 7B (Upland Transition). This strip transect traverses through upland sagebrush interspersed with immature pinyons and junipers.

Table 3-4-19 (Continued)

Transect 8 (Willow Creek). This steep, north-facing slope traverses east to west through a mixed mountain shrub habitat. A sparse overstory of pinyon pine and juniper is scattered throughout the transect, while a dense mixture of serviceberry, Gambel's oak, sagebrush, and snowberry compose the understory.

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aided in identifying the within-season variability of the avian population residing along a transect. For example, the likelihood of encountering mobile flocks and intermittently active birds increases with more exposure to an area.

3.4.4.3.1.2 Qualitative Songbird Censuses

Qualitative censusing was used to achieve a more complete inventory of species which utilize both the major Tract habitats sampled by quantitative censusing, and those edge habitats and small but unusual habitats that cannot be properly surveyed by strip transect techniques. The qualitative censuses were conducted during each general sampling period (Table 3-4-18).

3.4.4.3.1.3 Upland Gamebirds

Field observations made during songbird, waterfowl, and raptor censuses have demonstrated the regular occurrence of only one upland gamebird, the mourning dove, on or close to the Tract. Distribution, abundance, and migratory patterns of this dove were determined by quantitative and qualitative songbird survey methods conducted during the 11 sampling periods.

3.4.4.3.1.4 Waterfowl and Shorebirds

Waterfowl and shorebird utilization of the study area was determined by censusing the W. Oldland Ranch Pond (NE1/4, NE1/4, Sec. 5, T35, R96W) and the P-L Ranch Pond (SW1/4, SE1/4, Sec. 26, T25, R97W), the two ponds closest to Tract C-b. Each of these ponds was visited between three and nine times (Average 7.5) during 11 sampling periods (Table 3-4-18).

3.4.4.3.1.5 Raptors

Raptorial birds include the vultures, hawks, eagles, falcons, and owls. Also included in this category, due to its similar ecological role, is the common raven (Craighead and Craighead 1969). Trends in utilization of Tract C-b and immediately contiguous habitats were determined for the various raptor species. During all field periods, all opportunistic raptor sightings were recorded. In the course of field investigations, locations of all raptor nests encountered were recorded. During the 1975 and 1976 nesting periods, these nests were revisited and watched for evidences of occupancy. In addition, during the nesting seasons extensive searches were made of all Tract habitats considered to provide suitable raptor nest sites.

During November 1974, May and December 1975, and May 1976, nocturnal ground surveys were conducted to assess owl activity on the study area (Pocket Figure 3-4-13).

Raptor food habit investigations were conducted during March, May, October, and December 1975, and during March and July 1976 to determine raptor use of prey species in the Tract vicinity.

3.4.4.4 Brief Methodological Description

A number of methodologies were employed to determine presence and numbers of songbirds, upland gamebirds, waterfowl, and raptors. A brief description of the methodologies is presented here; a more detailed description, combined with a presentation of general data efficacy, is included in Appendix IV-A, Section 4.3. Nomenclature in the avifauna section follows the American Ornithological Union Checklist of North American Birds, fifth edition and the 32nd supplement.

3.4.4.4.1 Census Measures

3.4.4.4.1.1 Quantitative Songbird Censuses

3.4.4.4.1.1.1 Data Collection

At each of the census sites, a strip transect census procedure was used to provide data from which bird densities were calculated. The particular technique employed consists of slowly walking through a strip approximately 800 m long and 122 to 244 m wide. During the first seven sampling periods, the transects at the eight census sites were 800 m long and 244 m wide. However, based on the results of these censuses, the transect widths were adjusted at some sampling locations so as to sample a fairly homogeneous habitat, as was recommended by Emlen (1971). Three transects (3, 6, and 8) were decreased in width from 244 m to 122 m. Because detections of most songbirds beyond the 122 m category rarely contribute more than a minor proportion of the total count (Emlen 1971), the elimination of the 122 m to 244 m distance category was not deemed as detrimental to the censusing effort as was the continued sampling of mixed habitat types by a single transect. A Wilcoxon signed rank-sum test (Lehman 1975) was used to compare the density estimates of breeding species obtained on the transects that had width adjustments, and it was found that modifying the strip widths leads to no significant change in population estimates.

3.4.4.4.1.1.2 Data Analysis

Estimates of population density for species observed on strip transects were determined by one of three methods described by Emlen (1971) and elaborated in Appendix IV-A. The density estimates are presented as number of birds/hectare.

Wilcoxon's rank-sum test (Lehman 1975) was used on selected data to test the comparability of estimates for important species one year apart during the breeding season, and the comparability of common species on the two pinyon-juniper transects during June 1976.

Once a population density estimate was computed, it was used to determine the percentage relative abundance (% RA) for each species. As employed here, % RA is defined as follows:

$$\% \text{ RA} = \frac{\text{Density of species A}}{\Sigma \text{ Density of all species}} \times 100$$

The Shannon-Weiner calculation (Pielou 1966) was used to compute indices of species diversity (H'), maximum diversity (H' max), and equitability (j) for each habitat type sampled by strip transect procedures.

3.4.4.4.1.2 Qualitative Songbird Census

Qualitative songbird surveys consisted of walking an approximately 250-m-long route within a given vegetation type, and recording on a data form all birds encountered, by species and numbers. Whereas strip transects were surveyed during early morning and pre-dusk hours, qualitative censuses were run during mid-day periods of lower bird activity. Quantification in these surveys did not occur, because their sole function was to develop a more thorough inventory of species inhabiting Tract habitats.

3.4.4.4.1.3 Upland Gamebirds

Mourning dove abundance and distribution were determined by the same methods used for sampling songbird populations.

3.4.4.4.1.4 Waterfowl and Shorebirds

Waterfowl and shorebird utilization of the W. Oldland Ranch Pond and the P-L Ranch Pond was determined by recording the number of individuals present on the pond by species, during a 15-minute observation period. Morning, mid-day, and evening surveys were conducted. Utilization in bird-use days was calculated according to methods of Banfield (1947).

3.4.4.4.1.5 Raptors

During all field periods, raptors were recorded as to observation location, species, and age class, when possible. All raptor nests encountered during the two-year baseline program were noted as to location, nest type, and nesting substrate. During the nesting period, the species occupying each active nest was determined, and a photograph was taken of each nest location.

Night owl surveys consisted of a road transect having 30 stops, located approximately 1.13 km apart (Pocket Figure 3-4-13). Surveys commenced within two hours after sunset at each stop, the census taker left the vehicle, walked approximately 15 m away, and recorded on a data sheet by species, the number of owls heard or observed during a 5-minute period.

Raptor pellets and casts collected from nesting, roosting, and feeding sites were labelled as to raptor species, collection location, and date. Pellet dissections were performed to determine raptor use of prey species. All identifiable prey species found in each pellet and identified prey remains were recorded and % RA of the various prey species was calculated for each raptor species and collection period. Mammalian prey species were identified by characteristic skeletal parts. The presence of vegetation, insect, and avian matter was also noted, but species identification of these materials was not performed.

3.4.4.4.2 Habitat Requirements for Principal Species

The assignment of "biological importance" to bird species is not always straight-forward. In general, knowledge of the ecological roles played by individual bird species is too sketchy to permit such an assignment, particularly if one must deal with many species of songbirds in a relatively large study area. In the case of songbirds, we may operationally consider that the relative abundance and frequency of occurrence of a species provide an index to its biological importance. Thus, any summation of the relative abundance and the relative frequency of a particular species provides an "important value" for that species. Such a value could approach a maximum only if the species were frequently encountered and were in large numbers during each encounter. However, an intermediate value could be obtained either by encountering at least one individual of the species on most transects, or by encountering a large number of individuals of that species on one or a few transects.

An importance value was calculated from the density estimates for most songbird species recorded during the breeding season on Transects 1, 2, 3, 4, 5B, 6, and 8. These values permit ranking the relative importance of each species in each habitat during the breeding season.

The importance value (IV) for each species in a given habitat is defined as follows:

$$\text{IV} = \text{Percent Relative Frequency} + \text{Percent Relative Abundance}$$

where,

$$\text{Percent Relative Frequency} = \frac{\text{\# of censuses species A is encountered during sample periods 5 and 10}}{\text{\# of census replications during sample periods 5 and 10}} \times 100$$

$$\text{Percent Relative Abundance} = \frac{\text{\#/ha of species A during sample periods 5 and 10}}{\text{\#/ha of all species during sample periods 5 and 10}} \times 100$$

Importance values were not calculated for Transects 5A, 7A, and 7B because these habitats were sampled on only one occasion during each breeding season. In the absence of census replication, the relative frequency will always be unity. For Transects 1, 2, 3, 4, 5B, 6, and 8, the two songbird species achieving the largest importance values were considered the principal breeding species within a habitat type. For Transects 5A, 7A, and 7B, the two most important species were assumed to be those achieving the largest relative abundance values.

Importance values and designations of important species were determined for breeding species. Estimates of breeding bird densities are far more reliable than estimates of abundance for migratory transients and wintering species. The rationale for this conclusion is developed in the section on General Data Efficacy, in Appendix IV-A.

Importance values were not calculated for aerially-feeding species such as swifts, swallows, and nighthawks, nor for wide-ranging species such as raptors, waterfowl, and shorebirds. No reliable density estimates are available for these bird species (See Appendix IV-A), so meaningful importance values could not be calculated. However, the more abundant waterfowl species and the mourning dove are assigned an importance due to their recreational and economic value as game species. The waterfowl species also derive a particular kind of importance as components of riparian communities, which are very restricted in the study region. The more abundant raptor species encountered in the region are considered important both because of their aesthetic value and because of their role as top-level carnivores in local food webs. The greater sandhill crane, another bird discussed later as an important species, either is or has been classified as threatened or endangered.

The general habitat requirements of "important" species occurring on Tract C-b were determined from a combination of baseline data, the available literature, and the experiences of the investigator. The habitat requirement information is strictly qualitative because very little site-specific ecological interrelationship investigations were conducted for songbirds on Tract C-b.

3.4.4.5 Results and Discussion

3.4.4.5.1 Data Summary

During 11 census periods, 136 species were observed within the study area (Appendix IV-B, Table B-4-7). We believe that all functionally important components of the Tract C-b avifauna are included in this tabulation. The more common bird species observed on the Tract are listed in Table 3-4-20. Many unlisted species of minor transient importance undoubtedly appear in the Tract vicinity from time to time during migration, so it is expected that the inventory of species utilizing habitats in the area will continue to expand. Certain of the species still anticipated to be sighted will be waterfowl having extremely limited recreational importance in the basin. Also, one endangered species, the peregrine falcon, is expected to occasionally hunt over and migrate through the Tract vicinity, and will certainly be observed in the future. In addition to the 136 species observed within the study area proper, project ornithologists have sighted 25 additional species in other portions of the Piceance Basin. These are the great blue heron, white-faced ibis, redhead,

Table 3-4-20 COMMON BIRD SPECIES OBSERVED ON TRACT C-b[1]

Species Common Name	Season of Observation			
	Fall	Winter	Spring	Summer
Mallard	X	X	X	X
Green-winged teal	X	X	X	X
Blue-winged teal	X	X	X	X
Cinnamon teal			X	X
Marsh hawk	X	X	X	X
Rough-legged hawk	X	X	X	
Red-tailed hawk	X	X	X	X
Golden eagle	X	X	X	X
American kestrel	X	X	X	X
Spotted sandpiper			X	X
Mourning dove	X		X	X
Screech owl		X		X
Great horned owl	X	X	X	X
Broad-tailed hummingbird				X
Horned lark	X	X		X
Scrub jay	X	X	X	X
Pinyon jay	X	X	X	X
Common raven	X	X	X	X
Black-capped chickadee	X	X	X	X
Mountain chickadee	X	X	X	X
Red-breasted nuthatch	X	X		
American robin	X	X	X	X
Townsend's solitaire	X	X	X	X
Hermit thrush				X
Mountain bluebird	X		X	X
Blue-gray gnatcatcher	X		X	X
Bohemian waxwing		X		
Red-winged blackbird	X	X	X	X
Evening grosbeak		X	X	
House finch	X	X	X	X
Red crossbill		X	X	
Green-tailed towhee	X		X	X
Rufous-sided towhee	X	X		X
Vesper sparrow	X		X	X
Gray-headed junco	X	X	X	X
Tree sparrow	X	X	X	
Chipping sparrow	X		X	X
Brewer's sparrow	X			X
Song sparrow	X	X	X	X

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[1] See Appendix Table B-4-7 for complete list of bird species observed on Tract C-b.

Swainson's hawk, peregrine falcon, merlin, blue grouse, Virginia rail, sora, semipalmated plover, long-billed curlew, Hammond's flycatcher, bushtit, pygmy nuthatch, brown creeper, cedar waxwing, gray vireo, Tennessee warbler, house sparrow, northern oriole, Cassin's finch, pine grosbeak, grasshopper sparrow, lark sparrow, and golden-crowned sparrow. It is likely that individuals of these species appear on Tract C-b from time to time, but their importance is expected to be negligible.

Fifty-two species were noted in Tract habitats during mid-winter; a minimum of 100 of the species tabulated in Appendix IV-B, Table B-4-7 is expected to nest in the general Tract vicinity.

3.4.4.5.2 Songbirds

Songbird species observed on and close to Tract C-b during 11 periods of field inventory, spanning the interval from early October 1974 through mid-July 1976, are listed in Appendix IV-B, Table B-4-7; numerically dominant species are discussed in the section on Interpretive Summary. Population density changes and species diversity changes in four principal habitats over the years of study are depicted on Figures 3-4-14 and 3-4-15. Importance values are tabulated in Table 3-4-21, for all breeding species. Density, bird species diversity, and dominance indices for each of the sampled habitats are compiled for each census period in Table 3-4-22.

Principal wintering species in the four dominant habitats are given in Table 3-4-23. Appendix IV-B contains the results of the Shannon-Weiner Diversity indices calculations (Appendix IV-B, Table B-4-8) and the results of the quantitative avian censusing program, (Appendix IV-B, Tables B-4-9 through B-4-22), including mean densities and 80 percent confidence intervals for species in those transects which were sampled in triplicate (Appendix IV-B, Tables B-4-20 through B-4-22).

3.4.4.5.2.1 Interpretive Summary of Census Results

3.4.4.5.2.1.1 Fall Sampling Periods

The September 1975 sampling period occurred near the beginning of the fall migration for many songbirds, while the October 1974 period appeared to be near the mid-point of migration. More summer residents were present during 1975 than 1974 censuses (Figures 3-4-14 and 3-4-15).

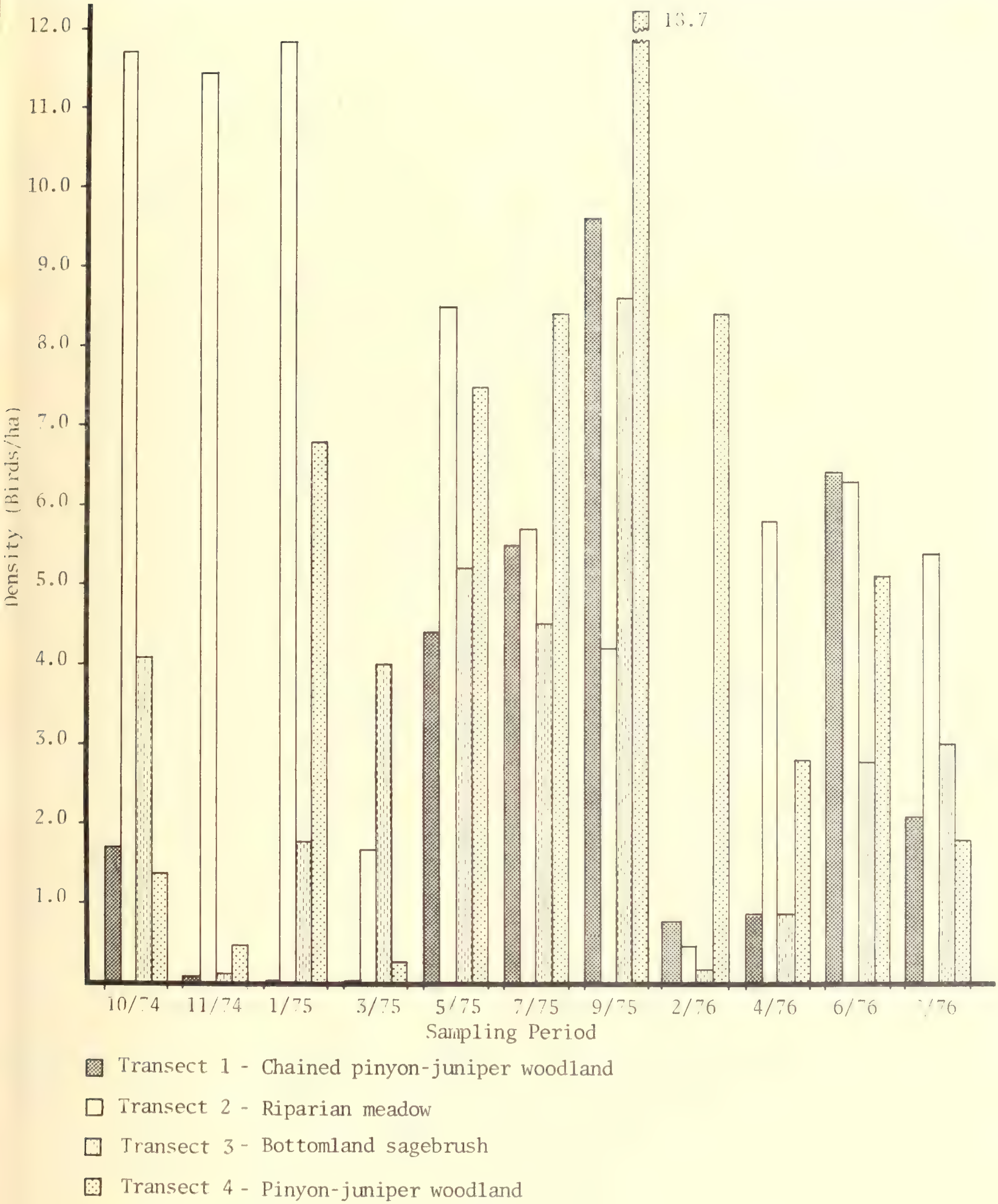

Figure 3-4-14 CHANGES IN TOTAL BIRD DENSITIES IN FOUR PRINCIPAL HABITATS OVER THE TWO YEARS OF STUDY.

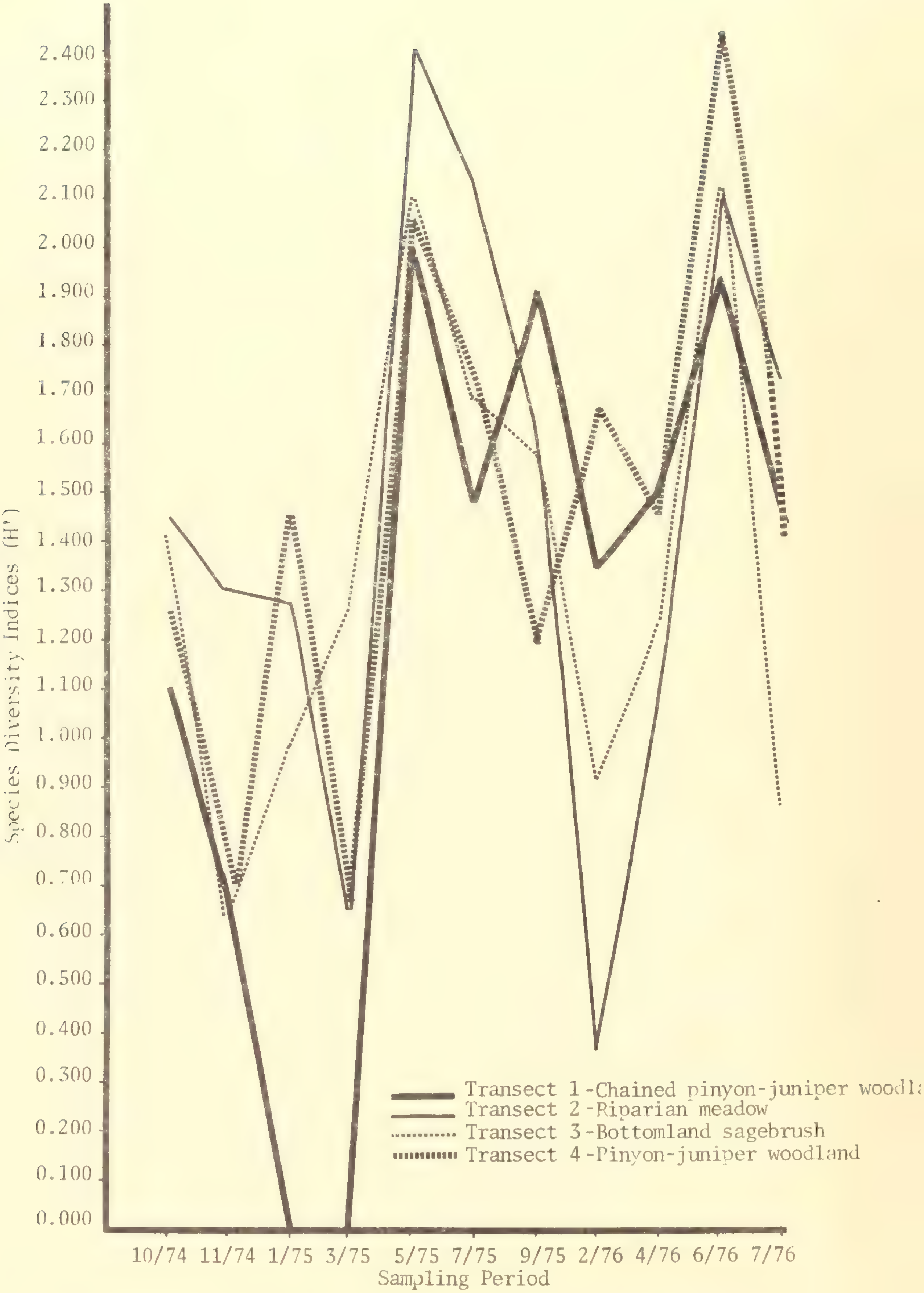

Figure 3-4-15 SPECIES DIVERSITY CHANGES IN FOUR PRINCIPAL HABITATS OVER THE TWO YEARS OF STUDY

Table 3-4-21 IMPORTANCE VALUES FOR EACH SONGBIRD SPECIES OBSERVED ALONG STRIP TRANSECTS CONDUCTED DURING MAY 1975 AND JUNE 1976, TRACT C-b SHALE OIL PROJECT

Species	Importance Values[1]						
	Transects[2]						
	1	2	3	4	5B	6	8
Mourning dove	76.0	25.0	25.0	78.0	104.0	51.0	
Common nighthawk				76.0	67.0		51.0
White-throated swift			27.0	26.0			51.0
Broad-tailed hummingbird	107.0	56.0	56.0	78.0	101.0	105.0	52.0
Belted kingfisher		25.0	25.0				
Common flicker	101.0	25.0		25.0	102.0	51.0	
Hairy woodpecker				25.0			
Cassin's kingbird		28.0					
Ash-throated flycatcher	27.0	25.0					
Say's phoebe							52.0
Dusky flycatcher				27.0			
Gray flycatcher					70.0	53.0	53.0
Western wood peewee		25.0					
Olive-sided flycatcher		27.0					
Barn swallow		76.0					
Cliff swallow		107.0	26.0	52.0		103.0	
Violet-green swallow		52.0	51.0	26.0	68.0	53.0	51.0
Tree swallow	25.4	53.0	29.0			50.0	
Rough-winged swallow		104.0	26.0				
Steller's jay				25.0	34.0		

Table 3-4-21 (Continued)

Species	Importance Values						
	Transects						
	1	2	3	4	5B	6	8
Scrub jay					101.0		
Pinyon jay				25.0	115.0		
Black-billed magpie					34.0		
Clark's nutcracker			52.0	25.0	34.0		
Common raven	50.6	25.0		25.0			
Mountain chickadee				79.0	105.0		54.0
Plain titmouse					37.0		
White-breasted nuthatch				76.0	68.0		
House wren	106.3	50.0	26.0	28.0	106.0		
Rock wren			80.0			52.0	
American Robin		103.0	25.0	52.0	68.0	53.0	55.0
Hermit thrush				105.0	36.0	53.0	
Mountain bluebird	104.1	50.0	80.0	79.0	105.0	66.0	
Blue-gray gnatcatcher	77.7	25.0	107.0		36.0		126.0
Solitary vireo				79.8	102.0	52.0	
Warbling vireo				31.0			
Orange-crowned warbler							
Virginia's warbler			53.0			53.0	61.0
Yellow-rumped warbler	40.3	28.0	33.0			53.0	
Black-throated gray warbler			41.0	31.0	110.0		52.0

Table 3-4-21 (Concluded)

Species	Importance Values Transects						
	1	2	3	4	5B	6	8
MacGillivray's warbler							
Red-winged blackbird		110.0					
Brewer's blackbird		84.0					
House finch	50.2		52.0	78.0	107.0	60.0	
Pine siskin		27.0		33.0			
Green-tailed towhee	116.6		81.0	28.0		112.0	123.0
Rufous-sided towhee					68.0	53.0	
Vesper sparrow	110.1		26.0	25.0		57.0	51.0
Black-throated sparrow	25.6						
Gray-headed junco			26.0	54.0	110.0	64.0	
Chipping sparrow		53.0		135.0	112.0	52.0	52.0
Brewer's sparrow	126.0	50.0	126.0			104.0	54.0
Song sparrow		118.0					

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[1] Importance value for each habitat =

$$\frac{\text{\#/ha of species A during sample periods 5 and 10}}{\text{total \#/ha of all species over sample period 5 and 10}} \times 100$$

$$+\ \frac{\text{\# of censuses species A is encountered during sample periods 5 and 10}}{\text{\# of census replications during sample periods 5 and 10}} \times 100$$

[2] Transect description is as follows: 1 = Chained pinyon-juniper woodland; 2 = Riparian; 3 = Bottomland sagebrush; 4 = Pinyon-juniper woodland; 5B = Pinyon-juniper woodland; 6 = Canyon sagebrush; 8 = Mixed mountain shrub

Table 3-4-22 SPECIES NUMBERS, DENSITIES, DIVERSITIES, AND DOMINANCE INDICES FOR AVIAN COMMUNITIES IN HABITATS DURING TWO-YEAR BASELINE PROGRAM[1]

Habitat (Transect)	Sampling Period Oct. 1974	Nov. 1974	Jan. 1975	Mar. 1975	May 1975	July 1975	Sept. 1975	Feb. 1976	April 1976	June 1976	July 1976
Chained pinyon-juniper woodland (1)											
Number of species	4	--	0	--	13	7	10	5	6	13	5
Density (birds/ha)	1.7	0.1	--	--	4.4	5.5	9.6	0.8	0.9	6.4	2.1
Dominance index	80.0	100.0	0	--	54.4	67.7	84.7	70.7	61.8	55.5	64.0
Diversity index (H')	1.1	0.7	0	--	2.0	1.5	1.2	1.3	1.5	2.0	1.4
Riparian meadow (2)											
Number of species	10	5	4	4	17	11	6	3	7	20	11
Density (birds/ha)	11.7	11.4	11.8	1.7	8.5	5.7	4.1	0.5	5.8	6.3	5.4
Dominance index	63.2	67.3	66.7	90.9	38.2	41.1	55.0	96.4	79.4	54.7	65.1
Diversity index (H')	1.5	1.3	1.3	0.7	2.4	2.1	1.6	0.4	1.1	2.1	1.7
Bottomland sagebrush (3)											
Number of species	7	2	3	4	12	11	11	3	6	16	3
Density (birds/ha)	4.1	0.1	1.8	0.5	5.2	4.6	8.6	0.2	0.9	2.8	3.0
Dominance index	73.2	100.0	91.5	66.6	47.3	64.5	71.2	81.3	82.4	53.7	86.4
Diversity index (H')	1.4	0.6	0.9	1.3	2.1	1.7	1.6	0.9	1.2	2.1	0.9
Pinyon-juniper woodland (4)											
Number of species	4	2	6	2	13	9	16	14	8	23	5
Density (birds/ha)	1.4	0.5	6.8	0.3	7.5	8.4	18.7	8.4	2.8	5.1	1.8
Dominance index	71.5	100.0	68.3	100.0	49.9	57.4	78.6	67.1	22.4	41.9	58.5
Diversity index (H')	1.3	0.7	1.5	0.7	2.1	1.7	1.2	1.7	1.4	2.4	1.4

Table 3-4-22 (Continued)

Habitat (Transect)	Sampling Period Oct. 1974	 Nov. 1974	 Jan. 1975	 March 1975	 May 1975	 July 1975	 Sept. 1975	 Feb. 1976	 April 1976	 June 1976	 July 1976
Pinyon-juniper woodland (5B)											
Number of species	--	--	--	--	--	--	--	10	14	25	--
Density (birds/ha)	--	--	--	--	--	--	--	30.4	3.4	7.0	--
Dominance index	--	--	--	--	--	--	--	96.7	61.6	27.5	--
Diversity index (H')	--	--	--	--	--	--	--	0.3	1.9	2.8	--
Mixed pinyon-juniper/sage/shrubs (5A)											
Number of species	2	--	4	--	11	--	4	--	--	--	--
Density (birds/ha)	0.3	--	4.6	--	4.4	--	0.6	--	--	--	--
Dominance index	100.0	--	86.5	--	62.3	--	83.4	--	--	--	--
Diversity index (H')	0.7	--	0.8	--	1.8	--	1.0	--	--	--	--
Canyon sagebrush (6)											
Number of species	1	--	5	--	9	--	6	7	8	17	--
Density (birds/ha)	0.1	--	10.8	--	3.1	--	2.8	11.5	1.9	4.6	--
Dominance index	100.0	--	90.5	--	46.7	--	70.6	82.6	42.4	31.1	--
Diversity index (H')	0	--	0.9	--	2.0	--	1.4	1.1	1.9	2.5	--
Upland sagebrush (7A)											
Number of species	0	--	0	--	10	--	6	--	--	--	--
Density (birds/ha)	0	--	0	--	5.8	--	1.9	--	--	--	--
Dominance index	0	--	0	--	57.5	--	69.9	--	--	--	--
Diversity index (H')	0	--	0	--	1.8	--	1.5	--	--	--	--

Table 3-4-22 (Concluded)

Habitat (Transect	Sampling Period Oct. 1974	Nov. 1974	Jan. 1975	March 1975	May 1975	July 1975	Sept. 1975	Feb. 1976	April 1976	June 1976	July 1976
Upland transition (7B)											
Number of species	--	--	--	--	--	--	--	7	6	11	--
Density (birds/ha)	--	--	--	--	--	--	--	1.9	1.2	4.1	--
Dominance index	--	--	--	--	--	--	--	55.9	69.8	38.8	--
Diversity index (H')	--	--	--	--	--	--	--	1.7	1.5	2.2	--
Mixed mountain shrub											
Number of species	3	--	6	--	6	--	4	3	0	12	--
Density (birds/ha)	2.5	--	10.7	--	2.3	--	0.6	1.5	0	4.7	--
Dominance index	80.7	--	63.9	--	56.6	--	83.3	86.7	0	47.5	--
Diversity index (H')	1.0	--	1.4	--	1.6	--	1.1	0.9	0	2.2	--

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[1] Does not include birds of prey, shorebirds, waterfowl, etc.

-- **Indicates no census was performed during this sampling period.**

Table 3-4-23 PRINCIPAL WINTERING SPECIES IN THE FOUR PRIMARY HABITATS ON THE TRACT C-b STUDY AREA

Species	% Relative Abundance		
Pinyon-juniper habitat	Transect 4[1]	Transect 4[2]	Transect 5B[3]
Red-breasted nuthatch	42.0	4.7	
Mountain chickadee	26.3	8.1	1.4
Pinyon jay	15.0	--	2.5
House finch	--	47.7	--
Red crossbill	--	19.4	0.3
Bohemian waxwing	--	--	94.2
Chained pinyon-juniper habitat	1	2	
Horned lark	--	38.6	
Red crossbill	--	32.1	
Rufous-sided towhee	--	19.3	
Bottomland sagebrush habitat	1	2	
Tree sparrow	48.6	--	
American robin	42.9	--	
House finch	--	62.5	
Evening grosbeak	--	18.8	
Scrub jay	--	18.8	
Riparian meadow habitat	1	2	
Horned lark	45.8	--	
Tree sparrow	20.9	--	
American robin	18.2	--	
Song sparrow	15.1	90.9	

[1] January 1975

[2] February 1976

[3] February 1976

3.4.4.5.2.1.1.1 Pinyon-Juniper Woodland

During the fall 1975 census, the pinyon-juniper woodland supported the highest density (Transect 4 -- 18.7 birds/ha). This high density resulted from a large flock of chipping sparrows having temporarily settled in the area at the time of the census. Because of this overwhelming dominance of one species, the species diversity index was low (H' = 1.2), even though 16 species were present (Table 3-4-22). Many summer residents of pinyon-juniper woodland (mourning dove, violet-green swallow, house wren, and black-throated gray warbler) had not departed from the area, and were flocking with migrants from the montane zone such as the Townsend's warbler and yellow-rumped warbler, and with permanent residents such as the mountain chickadee and white-breasted nuthatch.

In October 1974, density (1.4 birds/ha) and number of species (4) were less in the pinyon-juniper woodland (Transect 4) than in September 1975. Only one summer resident, the mountain bluebird, remained in small flocks (about 0.2 birds/ha); three common winter residents of the Tract vicinity, black-capped chickadee, Townsend's solitaire, and robin, were also present.

3.4.4.5.2.1.1.2 Pinyon-Juniper/Mixed Mountain Shrub

During both fall censuses of the pinyon-juniper/mixed mountain shrub transect, only winter and permanent residents were recorded in low numbers. The fall variations between the two pinyon-juniper woodland transects during early autumn (as well as the variations noted on transects through other habitats) can be attributed to the flocking behavior of most species during migration. A more detailed discussion of causative factors for such variations is given in Appendix IV-A.

3.4.4.5.2.1.1.3 Chained Pinyon-Juniper Woodland

During September 1975, the vesper sparrow, Brewer's sparrow, and song sparrow contributed 92 percent of total relative abundance in the chained pinyon-juniper woodland habitat. A single song sparrow was recorded; its relative density was markedly overestimated by the computational formula, because the single observation was made very close to the census taker. The song sparrow was then excluded from consideration as an important constituent of the chained pinyon-juniper woodland. During October, the Brewer's sparrow and vesper sparrow were no longer present in this habitat, and the gray-headed junco, yellow-rumped warbler, mountain bluebird, and Townsend's solitaire were recorded in small numbers.

3.4.4.5.2.1.1.4 Riparian Meadow

The riparian meadow habitat supported a low density of birds during September (4.1 birds/ha), but it exhibited the highest density (11.7 birds/ha) and species diversity (H' = 1.46) of the transects sampled during October (Figures 3-4-14 and 3-4-15; Table 3-4-22). Apparently, many of the species that had been nested in this habitat, such as the broad-tailed hummingbird and cliff swallow, had left the area by the September census, and many species that breed in other habitats but congregate during the fall and winter in the riparian valleys had not yet arrived. In October, migrants such as the yellow-rumped warbler and the white-crowned sparrow were present along with two typical winter residents, the song sparrow and house finch. Also, a large pre-migrational flock of red-winged blackbirds contributed to the high October density estimate.

3.4.4.5.2.1.1.5 Bottomland Sagebrush

Vesper sparrows and Brewer's sparrows were the principal components of the bird community in the bottomland sagebrush habitat during September; together, these species comprised 71 percent of the relative density. These species confined their activities to the shrubs along the valley floor. House wrens and rock wrens also made significant contributions to density, but the remaining seven species tallied during September were present in low densities. Rock wren activity occurred principally on the rocky slopes forming the gulch sides; the pinyon-juniper cover along these slopes attracted the common flicker, Clark's nutcracker, mountain chickadee, white-breasted nuthatch, and blue-gray gnatcatcher.

3.4.4.5.2.1.1.6 Other Habitats

The canyon sagebrush, mixed mountain shrub, and upland sagebrush habitats all exhibited low avian densities during September, ranging from 2.7 birds/ha in canyon sagebrush to 0.6 birds/ha in mixed mountain shrub. Only 13 species were recorded in these three brushland habitats. Breeding species such as the green-tailed towhee, vesper sparrow, and mourning dove were abundant in canyon sagebrush habitat. Brewer's sparrows, pinyon jays, mountain chickadees, and violet-green swallows accounted for approximately 63 percent of relative abundance; of these, only the Brewer's sparrow restricted its activities to sagebrush cover. The other three favored the surrounding pinyon-juniper woodland, and alighted only occasionally within the sagebrush community. Only four species (scrub jay, Clark's nutcracker, mountain chickadee, and rufous-sided towhee) were noted in the mixed mountain shrub habitat, and none achieved a density worthy of characterizing it as a numerically important species.

During October, only four species were recorded in these three habitats. The Townsend's solitaire was present in the scattered trees associated with the canyon sagebrush transect, and mountain chickadees, ruby-crowned kinglets, and western flycatchers were recorded in small numbers within the mixed mountain shrub habitat. No birds were noted in the upland sagebrush habitat during October. Strong winds at the time of sampling made these habitats unattractive to most species.

3.4.4.5.2.1.2 Winter Sampling Periods

By late November, most summer residents and migratory species had left the Tract region, and more winter residents had appeared. Many of the wintering species fed and rested in loosely organized flocks which appeared to move over large portions of the Tract and feed in a variety of different habitats. Therefore, it is difficult to discuss the wintering bird communities on a habitat-by-habitat basis as was done for the fall sampling period. As in October, only the riparian meadow supported a dense assemblage of birds (11.9 birds/ha vs. 0.5 birds/ha for the second densest habitat); it also achieved a moderately high diversity of species (H' = 1.3). At the time of censusing, large flocks of American robins and starlings were foraging in the meadow bordering Piceance Creek. Song sparrows were the only other birds present in substantial numbers. Although a few white-crowned sparrows and a single red-winged blackbird were still present, the bird species composition of the riparian meadow had changed markedly between early October and late November. This was also the case for the other three transects sampled during November (Appendix IV-B, Tables B-4-9 and B-4-10). Black-billed magpies, northern shrikes, white-breasted nuthatches, Townsend's solitaires, and American robins were the only birds recorded within the three transects.

Virtually all summer residents and migrant species observed during the early and late fall inventory periods had departed the Tract by January 1975. Individuals of certain migratory species such as the horned lark and American robin which were present in January were most likely birds that moved into the area subsequent to nesting in more northerly localities. Others probably summered at nearby higher elevations and descended into lower parts of the Piceance Basin for the winter. Table 3-4-23 summarizes the principal wintering songbird species for the four major habitats in the study area.

During the 1975 winter, the riparian meadow habitat supported the densest bird population of all transects, but its density was almost equalled by bird numbers in the mixed mountain shrub habitat (Table 3-4-22). As a consequence of large flocks of horned larks and American robins present in meadows bordering Piceance Creek, species equitability was relatively low in this habitat and the pinyon-juniper woodland transect (4) attained the highest species diversity index (H' = 1.5).

During the 1976 winter, the pinyon-juniper woodland (Transect 5B) supported the highest bird density recorded during the baseline study (30.4 birds/ha). However, a low species diversity index was calculated (H' = 0.32) because of the overwhelming preponderance of Bohemian waxwings encountered.

Although avian density was slightly lower in the pinyon-juniper woodland habitat sampled by Transect 4 (8.4 birds/ha), species diversity at Transect 4 was considerably higher (H' = 1.67). This is attributed to the greater number of species and higher equitability value (14 species; J = 0.633) compared to Transect 5B (10 species; J = 0.137).

Differences existed between the two pinyon-juniper transects' species composition recorded during February 1976, and January 1975. During 1975, only two species were recorded which were common to both transects. During February 1976, seven species on Transect 4 were not recorded on Transect 5B. Despite the differences, it is expected that the species recorded within the two transects are probably representative of the avian community utilizing most pinyon-juniper stands of the Tract area during portions of most winters. The variation in species composition and densities between the two transects simply reflects the inconsistent pattern of habitat utilization caused by the dynamic behavior of winter flocks.

Two habitat types, the chained pinyon-juniper woodland and the upland sagebrush, were subjected to severe conditions by winter winds. Birds were not present on transects censused in either of these habitats during January 1975. Even during the milder winter of 1976 low bird densities, in comparison with densities in protected canyon sagebrush habitats (11.5 birds/ha), were recorded in both the chained (0.8 birds/ha) and upland transition habitats (1.9 birds/ha); the upland transition transect appeared comparable to the upland sagebrush transect in terms of wind characteristics and snow accumulation patterns.

Moreover, no birds were tallied in the chained pinyon-juniper transect during March 1975, and during November 1974 this transect sustained the lowest density of the four transects censused in that month (0.1 birds/ha). During April 1976 it supported the third lowest density of the eight transects sampled in that month (0.9 birds/ha). Based on these observations combined with few sightings on qualitative counts made in the chained pinyon-juniper woodland habitat type during winter, it appears that the extensive chaining which occurred during the mid-1960's has markedly affected winter distribution of birds on the Tract.

The species composition of the avian communities encountered during February 1976 differed substantially from that of the January 1975 censuses (Appendix IV-B, Tables B-4-11 and B-4-16). Evening grosbeaks, red crossbills, Bohemian waxwings, and house finches, were present during 1976 but were not recorded during the first winter of sampling. These species tend to appear sporadically but in large numbers during winter in certain portions of the nation. According to Warren Keammerer, Principal Investigator for vegetation studies on Tract C-b, the junipers in the Piceance Basin had a fairly productive fruiting year during 1975; this could be one factor contributing to the large concentrations of Bohemian waxwings wintering on Tract C-b during the 1975-76 winter. The red crossbill and evening grosbeak occur irregularly in Colorado, being very numerous in a given area at times, and completely absent at others (Bailey and Niedrach 1965). The house finches, red crossbills, and evening grosbeaks were repeatedly observed feeding on pinyon cones. Seed years for pinyon pines usually occur at five-year intervals (Phillips 1909); 1975 may have been a highly productive seed year for the mature pinyon trees in the Tract area, thereby accounting for the attractiveness of the region to the finches, grosbeaks, and crossbills. Moreover, this would account for the abundance of birds present in the pinyon-juniper woodland habitat compared with the few birds encountered in the shrub and riparian habitats throughout the study area. These irregular invasions of the pinyon-juniper woodland habitat by evening grosbeaks, red crossbills, Bohemian waxwings, and house finches have also been documented in other parts of the Piceance Basin, Rio Blanco Oil Shale Project.

The absence during the 1976 winter season of species which were common during January 1975 (e.g., dark-eyed juncos, gray-headed juncos, tree sparrows) also demonstrated a marked difference in species composition from winter to winter. These species were also noted to be much sparser than usual in certain Colorado Christmas counts conducted during December 1975. Significant changes in the composition of a wintering population in a seasonal environment are sometimes associated with periods of prolonged snow cover and low ambient temperature (Kind and

Wales 1964). The numbers of some species will increase during these conditions while others decrease in numbers. The snow conditions and temperatures in the region and at northern latitudes have varied during the past two winter seasons and this probably has contributed in part to differences in wintering avian communities.

3.4.4.5.2.1.3 Spring Sampling Periods

3.4.4.5.2.1.3.1 Mid-March

In mid-March, most songbirds on the Tract were still in mixed flocks; although these flocks were observed in the Tract vicinity, no flocks were encountered during actual censuses of four transects. Thus, low densities were recorded on all transects (Table 3-4-22). Again, the riparian meadow habitat achieved the highest density value (1.7 birds/ha), but this value was much lower than for any other census period. The bottomland sagebrush transect exhibited the highest species diversity index (H' = 1.3). Qualitative censuses indicated that most winter residents were, in fact, still present on the Tract. Large groups of dark-eyed and gray-headed juncos were encountered, and other wintering birds (Clark's nutcracker, Townsend's solitaire, northern shrike, and tree sparrow) had not yet departed for higher elevations or more northern latitudes. March was nonetheless a period of change in species composition, as the vanguard of migrant and summer resident species was arriving. Red-winged blackbird congregations were observed in riparian meadows near the Tract, and migrating mountain bluebirds were conspicuous in open vegetative communities which contained scattered trees.

3.4.4.5.2.1.3.2 Mid-April

Field investigations conducted during mid-April 1976 demonstrated further compositional changes. Most winter residents were no longer in the area by mid-April. Many summer residents, such as the Say's phoebe, mourning dove, rough-winged swallow, and green-tailed towhee, were present in small numbers. Some early arriving summer residents, such as the mountain bluebird and vesper sparrow, had already established breeding territories.

As in March, population densities were greatest in the riparian meadow habitat during April (5.8 birds/ha), while the highest species diversity was recorded in the pinyon-juniper woodland (Transect 5B) and the canyon sagebrush (H' = 1.9).

The variation in species density and composition between the March 1975 and April 1976 spring census periods is probably attributable to slight differences in timing of the censuses, resulting in different mixes of winter residents, migrants, and summer residents being tallied. During transitional periods of migration, the proportions of species in each of these residence status categories can change rapidly. Moreover, a greater number of species was recorded during the April surveys, probably as a result of the increased sampling intensity that occurred subsequent to sample period seven (Table 3-4-22).

3.4.4.5.2.1.4 Summer Sampling Periods

Species diversity was higher during late spring and early summer than during any other sampling period (Figure 3-4-15). At this time, virtually all summer residents were present, and territorial activities made most species audibly and visually conspicuous.

Based on importance value calculations (Table 3-4-21) Brewer's sparrow was dominant in the chained pinyon-juniper woodland and bottomland sagebrush habitats. The green-tailed towhee was a principal species in the chained pinyon-juniper woodland, mixed mountain shrub, and canyon sagebrush habitat, and the blue-gray gnatcatcher was important in the bottomland sagebrush. The gnatcatcher also achieved importance in the mixed mountain shrub communities, where it shared this designation with the broad-tailed hummingbird. The two important species associated with the riparian meadow habitat were the red-winged blackbird and song sparrow. The chipping sparrow was an important species in both pinyon-juniper woodland transects. However, the hermit thrush attained higher importance than the chipping sparrow in the ridgetop pinyon-juniper (Transect 4) woodland, while the gray-headed junco obtained higher importance in the east slope pinyon-juniper woodland (Transect 5B).

Although the most abundant species recorded along the pinyon-juniper/mixed brush transect during summer 1975 was the western wood pewee, it is not considered an important breeding species of this habitat type. Two individuals were recorded, but its relative density (1.6 birds/ha) was undoubtedly overestimated due to inadequate sample size and its close distance to the census taker at time of observation. This species was not recorded in other pinyon-juniper woodland habitats during the 1975 or 1976 breeding seasons. The individuals recorded in the pinyon-juniper/mixed brush transect were probably late migrants enroute to Douglas fir or other forests at some distance from the study area. The important nesting species within the pinyon-juniper/mixed brush habitat were the chipping sparrow and mountain bluebird.

The abundant species in upland transition and upland sagebrush habitats were the vesper sparrow, chipping sparrow, and Brewer's sparrow. These three species are considered important breeding species in such upland habitats.

During May 1975, the riparian meadow transect exhibited the highest density (8.5 birds/ha) and the greatest species diversity (H' = 2.58). The pinyon-juniper woodland at Transect 4 attained the second highest density (7.5 birds/ha), while the bottomland sagebrush transect exhibited a diversity index of 2.12, the second highest diversity recorded (Figures 3-4-14, 3-4-15 and Table 3-4-22).

The three principal habitats (riparian meadow, pinyon-juniper woodland, and bottomland sagebrush) sampled during June 1976 supported lower densities than were present during the 1975 breeding season as censused in late May (Figure 3-4-14). Conversely, the chained pinyon-juniper woodland, canyon sagebrush, and mixed mountain shrub transects exhibited higher total densities during 1976. Wilcoxon's rank = sum test was used to compare the density estimates for principal breeding species obtained for transects sampled during both 1975 and 1976. Results indicate that densities for these species were significantly different between the two years with fewer individuals present during 1976.

The decreased avian densities noted in the three principal habitats during 1976 were perhaps attributable to the decreased grass, forb, and shrub productivity on the study area and other parts of the Piceance Basin (Rio Blanco Oil Shale Project 1976b, 1976c) in comparison with the 1975 summer. This could affect the food availability for the herbivorous species. A decrease in food availability has been correlated with an increase in the size of the territory defended by breeding males (Cody 1974). This would have a causal effect on the breeding densities of those species. The decreased productivity may also have affected the amount of nesting cover available to shrub and ground-nesting species.

In addition, a decreased number of terrestrial invertebrates were recorded during 1976 quantitative investigations of insect abundance conducted in other regions of the Piceance Basin. This decreased invertebrate availability might have influenced the numbers of insectivorous and omnivorous birds nesting on the study area.

In contrast to other habitats, densities of 11 species nesting in the chained pinyon-juniper woodland increased from 1975 to 1976. Conner and Adkisson (1975) studied the effects of clearcutting on the diversity and density of breeding birds and concluded that clearcutting initially reduces breeding bird density, but that later, abundance tends to increase with increasing age of the recolonization community. This trend is expected on Tract C-b.

The "significant" increase in breeding populations of the principal species in the canyon sagebrush and mixed mountain shrub habitats is perhaps an artifact of the low sampling intensity rather than to real differences in population numbers. These transects were not sampled in replicate. Thus, determination of within-season variability of the strip transect data is not possible and statistical comparisons would not be meaningful.

During June 1976, 23 species and 25 species were recorded along the two pinyon-juniper woodland transects (Transects 4 and 5B, respectively). More than 72 percent of these species were observed in both transects. A Wilcoxon signed rank-sum test was used to test if species common to both pinyon-juniper woodland transects during the 1976 breeding season have the same population densities. No significant difference was noted between the two populations, indicating that the two pinyon-juniper woodland habitats supported similar breeding populations during 1976. The slight variations in species composition is probably attributed to differences in the shrub stratum of the two transects. Transect 5B supports a sparser overstory of trees and a denser and more varied understory than is found in Transect 4. This structural difference probably accounts for the greater variety of brush-inhabiting species on Transect 5B, such as rufous-sided towhees and blue-gray gnatcatchers.

A major difference in breeding species composition between the chained pinyon-juniper transect and the adjacent pinyon-juniper transect (5B) was evident during 1976. Of the 25 species noted in the pinyon-juniper transect, only seven were recorded in the chained pinyon-juniper woodland. These seven are species generally associated with the shrub stratum in the pinyon-juniper woodland (such as the blue-gray gnatcatcher) or species which are cosmopolitan and therefore not restricted to one habitat type for nesting and feeding (such as the mourning dove and mountain bluebird). These data demonstrate that chaining drastically altered the species composition from that of the original woodland.

Of the four principal habitats sampled during July, the pinyon-juniper woodland attracted the highest density (8.4 birds/ha) during 1975 and the riparian meadow supported the most individuals during 1976 (5.4 birds/ha) (Figure 3-4-14). However, species diversity was highest in the riparian community during 1975 and 1976 (H' - 2.1 and 1.7, respectively, Figure 3-4-15).

The apparent variation in population density during the

July 1975 and 1976 sampling periods (Figure 3-4-14) may in part have resulted from the low sampling effort during July and the decreased visual and audible conspicuousness of many birds subsequent to hatching of their young. Such inconspicuousness introduces variability into census results, despite the care taken in data collection.

3.4.4.5.2.1.5 Summer-Winter Changes

Between late spring and mid-summer of both years, 74 songbird species were recorded on and near the Tract (Appendix IV-B, Table B-4-7). Comparison of relative density values for principal species in the four major Tract habitats for winter and summer censuses demonstrates that the Tract's avifauna changes markedly from winter to summer. During winter, habitats in the vicinity tend to support fewer species. Most breeding species leave the Piceance Creek basin to winter at locations farther south. In woodland and shrub habitats, 74 to 94 percent of the breeding songbird species did not remain through the winter. In riparian meadow habitats along Piceance Creek, 90 percent of nesting songbird species were migratory. Wiens and Dyer (1975) indicated that a high migratory propensity is typical of shrub steppe avifaunas, and believed that the available supply of winter food (principally seeds) is lower in shrub communities than in grassland communities, thus accounting for a fall exodus from shrub habitats by breeding birds.

The dominance index, which summarizes relative densities for the two species achieving greatest density, indicated that most avian communities on the Tract are dominated by only two species (Table 3-4-22). The breeding assemblages of birds in Tract habitats are simple in structure. The summary values in Table 3-4-22 also demonstrate substantial seasonal variations in density for most habitats. Certain reasons for these variations are described in the section on general data efficacy (Appendix IV-A). In addition, it is clear that the Tract supports fewer birds during some seasons than others. It is probable that such seasonal variations in density are characteristic of the surveyed habitats. Based on the analysis of differences in density of the principal breeding species and recent literature on seasonal and annual variations in bird densities (Wiens 1975a, Wiens and Dyer 1975, Balda 1975), it is expected that marked year-to-year variations in breeding densities will occur. As indicated by the two years' data (Appendix IV-B), it is anticipated that species composition of the breeding bird communities will remain relatively stable from year-to-year in the absence of major disturbances in all habitats except the chained pinyon-juniper woodland. There, normal vegetative succession will foster changes in bird species composition and density.

Based on average densities of birds over 11 census periods, the pinyon-juniper woodland habitat supported the greatest number of birds (mean density = 7.2 birds/ha); the riparian meadow habitat averaged the second highest density (6.6 birds/ha), while the upland transition habitat ranked the poorest (2.4 birds/ha).

3.4.4.5.3 Upland Gamebird Observations

Only two species of upland gamebirds, the mourning dove and sage grouse, were observed within the study area. Based on droppings which have been noted in sagebrush cover immediately south of the Tract, it is clear that few sage grouse inhabit the vicinity. Sage grouse signs, in the form of tracks and droppings, have been seen only once on Tract C-b proper. Sagebrush communities on the Tract are not sufficiently large to support a sage grouse population. Hence, the presence of leks or nesting concentrations on the study area is not anticipated. Blue grouse habitat appears restricted to points southeast and south of the Tract. No blue grouse individuals were observed during this two-year investigation period.

During the 1975 and 1976 nesting seasons, mourning doves were recorded in every habitat on the Tract. The nesting density of this species varied from 0.03 birds/ha in the bottomland sagebrush to 0.25 birds/ha (Appendix IV-A) in the pinyon-juniper woodland. The mourning dove was most abundant in pinyon-juniper woodlands adjacent to expanses of chained habitat (Transect 5B) and in upland transition areas of sagebrush and scattered, young pinyon and juniper growth along Transect 7B. These habitats provide trees suitable for roosting, daytime resting, and nesting, and are interspersed with open areas containing ample supplies of forbs and weeds, common food items of the mourning dove (Davis and Anderson 1973).

Fall migration of doves usually commences in September. Prior to migration, large flocks usually congregate along streams and in bottomland sagebrush and open pinyon-juniper communities reasonably close to water. This flocking tendency is exemplified by the increased densities recorded during the fall censuses. During October 1974, densities of up to 0.6 birds/ha were recorded in the riparian meadow habitat along Piceance Creek. During September 1975, 0.5 birds/ha and 0.2 birds/ha were recorded in the canyon sagebrush and pinyon-juniper woodland habitats.

Mourning doves began reappearing in the Tract vicinity in early April. They congregated along Piceance Creek after their initial arrival, and remained there until dispersing in pairs to specific breeding sites during late April.

3.4.4.5.4 Waterfowl

Information on waterfowl and shorebird usage of the open water and riparian habitat on the study area was determined by repeated censuses at the P.L. Ranch and W. Oldland Ranch impoundments throughout the baseline program. Twenty-four waterfowl and shorebird species were recorded on the study area during the baseline program (Appendix IV-B, Table B-4-7). Of these, 11 (46 percent) species nest in the area. The majority of the water fowl species that occur on the study area are migrants or winter residents.

Waterfowl populations within the study area are concentrated along Piceance Creek and its associated ponds. Limited usage occurs of the Piceance Creek tributaries that traverse the study area. The paucity of open water within the study area is undoubtedly the major limiting factor on the size of the resident and migratory waterfowl population.

Waterfowl usage was greater on the P.L. Ranch pond than on the W. Oldland Ranch pond (Tables 3-4-24 and 3-4-25). The fluctuating depth of the W. Oldland Ranch pond, the sparse nature of its shoreline vegetation, and its proximity to the Stewart Gulch road probably account for the low year-round usage of this pond compared to the P.L. Ranch pond. For this reason, the data from the P.L. Ranch pond are used to portray general trends of waterfowl utilization on the Tract C-b study area.

Variations in daily waterfowl abundance noted during the baseline program are probably a consequence of the wide-ranging movements of these birds. For example, mallards have been noted to fly 15 to 25 miles from an aquatic resting site to foraging areas (Johnsgard 1975a). Many individuals that utilize the study area probably do not restrict their activities to Tract C-b and its immediate environs and may not return to the same pond for nesting each day. Such movements over large areas preclude effective estimation of waterfowl usage on a small site such as the study area.

During October 1974, usage of the P.L. Ranch pond by waterfowl was the highest recorded during the study [46 average bird-use days (ABUD)]. In comparison, waterfowl usage was considerably lower during September 1975 (18 ABUD).

The utilization differences between the two fall sampling periods is partially due to the time of the month in which the surveys were conducted. During September, many female ducks that breed in the area are in a postnuptial molt. During the molt, the birds become flightless and are rarely seen (Keith 1961).

Table 3-4-24 RESULTS OF SHOREBIRD AND WATERFOWL COUNTS CONDUCTED AT P-L RANCH POND DURING THE TWO-YEAR BASELINE PROGRAM, TRACT C-b SHALE OIL PROJECT

	Average Bird-Use Days[1]										
	Fall		Winter			Spring		Summer			
Species	Oct. 1974	Sept. 1975	Nov. 1974	Jan. 1975	Feb. 1976	Mar. 1975	Apr. 1976	June 1975	June 1976	July 1975	July 1976
Mallard	28.9	1.3	12.7	10.3	5.1	4.5	12.3	1.5	9.4	1.0	0.4
Northern shoveler	0.3	0.3	--[2]	--	--	--	--	--	--	--	--
American wigeon	1.0	--	2.7	0.7	19.5	--	--	--	--	--	--
Gadwall	--	--	0.7	0.6	--	--	0.8	--	--	--	--
Pintail	--	--	--	--	--	0.3	--	--	--	--	--
Green-winged teal	4.3	1.5	14.0	9.0	7.0	14.3	11.2	1.5	3.9	3.3	2.1
Blue-winged teal	10.0	12.7	0.7	--	0.5	--	1.0	0.4	--	--	0.3
Cinnamon teal	--	--	--	--	--	1.0	6.3	4.2	0.3	3.3	0.3
Red-breasted merganser	--	--	--	0.7	--	--	--	--	--	--	--
Ring-necked duck	--	--	--	--	--	--	0.3	--	--	--	--
Common goldeneye	--	--	--	2.7	1.9	0.4	2.3	--	--	--	--
Barrow's goldeneye	--	--	--	0.1	--	--	--	--	--	--	--
Bufflehead	--	--	--	2.4	--	--	--	--	--	--	--
American coot	1.2	--	2.0	--	--	--	0.1	0.4	0.8	1.1	2.1
Killdeer	--	--	--	--	--	--	0.5	--	--	--	--
Greater yellowlegs	--	--	--	--	--	--	0.3	--	--	--	--
Lesser yellowlegs	--	0.2	--	--	--	--	--	--	--	--	0.6
Solitary sandpiper	--	1.0	--	--	--	--	--	--	--	--	0.3
Spotted sandpiper	--	--	--	--	--	--	--	4.5	1.9	--	0.9
Wilson's phalarope	--	--	--	--	--	--	--	13.0	0.2	6.1	0.5
Common snipe	--	--	--	--	--	--	--	0.2	--	--	--
Unidentified teal	--	1.0	--	--	--	--	--	--	--	--	--
Unidentified duck	--	--	--	--	--	--	0.3	--	--	--	--
TOTAL	45.7	18.0	32.8	26.5	34.0	20.5	36.2	25.7	16.5	14.8	7.5

[1] Average Bird-Use Days = $\frac{\text{Total number of species A/sampling period}}{\text{Total number of observation periods/sampling period}}$

[2] -- = not recorded during sampling period

Table 3-4-25 RESULTS OF SHOREBIRD AND WATERFOWL COUNTS CONDUCTED AT W. OLDLAND RANCH POND DURING THE TWO-YEAR BASELINE PROGRAM, TRACT C-b SHALE OIL PROJECT

	Average Bird-Use Days[1]										
	Fall		Winter			Spring		Summer			
Species	Oct. 1974	Sept. 1975	Nov. 1974	Jan. 1975	Feb. 1976	Mar. 1975	Apr. 1976	June 1975	June 1976	July 1975	July 1976
Pied-billed grebe	--[2]	--	--	--	--	--	--	0.3	--	--	--
Mallard	--	--	--	12.9	--	5.7	0.4	0.7	--	--	--
American wigeon	--	--	--	3.3	0.4	1.0	--	--	--	--	--
Pintail	--	0.1	--	--	--	--	--	--	--	--	--
Green-winged teal	--	4.3	--	--	--	--	0.2	--	--	--	1.8
Blue-winged teal	--	7.8	--	--	--	--	--	0.7	--	--	--
Cinnamon teal	--	--	--	--	--	--	--	1.6	--	--	--
Common goldeneye	--	--	--	0.5	0.2	0.2	--	--	--	--	--
Killdeer	--	--	--	--	--	--	0.5	--	0.1	--	0.2
Solitary sandpiper	--	0.1	--	--	--	--	--	--	--	--	--
Spotted sandpiper	--	--	--	--	--	--	--	0.3	--	--	0.7
Wilson's phalarope	--	--	--	--	--	--	--	0.5	--	--	--
Common snipe	--	--	--	--	--	--	--	0.2	0.5	--	--
TOTAL	0.0	12.3	0.0	16.7	0.6	6.9	1.1	4.3	0.6	0.0	2.7

[1] Average Bird-use Days = $\frac{\text{Total number of species A/sampling period}}{\text{Total number of observation periods/sampling period}}$

[2] -- = not recorded during sampling period.

Female mallards remain in this state for 24 to 26 days (Boyd 1961). The sparsity of observations of this species during September was probably a direct consequence of this secretive behavior of female ducks during molting.

Another factor contributing to the variation in results between the two fall census periods is the fact that more migratory ducks are in the area during October than in September. Although the Piceance Basin is not recognized as a segment of any major migratory route within the Pacific waterfowl flyway, some migratory waterfowl species do move through the area during the fall and utilize the impoundments along Piceance Creek as stopovers. Also, waterfowl from other parts of the study area and other regions of the Piceance Basin having diminished water supplies as fall progresses, probably congregate in the Piceance Creek area during autumn. Unlike ducks, most sandpipers appeared to have left the Piceance Basin by the end of September; this explains their absence during October censuses.

During winter, the mallard, green-winged teal, and American wigeon were the most abundant species along Piceance Creek. The mallard and green-winged teal are the only abundant permanent residents of the study area. The American wigeon apparently begins migrating into the Piceance Basin during October and leaves by March (Tables 3-4-24 and 3-4-25). The blue-winged teal, a common resident in early fall, was present in only low numbers during winter. According to Johnsgard (1975a), the blue-winged teal migrates out of the colder portions of its breeding range to a greater extent than any other North American duck species.

The gadwall, common goldeneye, bufflehead, and American coot were also encountered in low numbers during the winter censuses. None of these species was present during both winters; all are probably irregular winter visitors along Piceance Creek.

Several unusual species were noted on the study area during winter. A male Barrow's goldeneye was identified on the P.L. Ranch pond during January 1975. The only other record of this species in this region was made by Good (1956), who observed a male on the Green River, northeast of Escalante Crossing. Four red-breasted mergansers were observed on the P.L. Ranch pond in late January 1975. Davis (1969) classified this species as an uncommon winter resident on open rivers. It has been reported as a frequent visitor along the Green River in northeastern Utah and northwestern Colorado during migration in early May and late September.

Mallard and green-winged teal remained the most common species on the P.L. Ranch pond during spring (Table 3-4-24). By March, the American wigeon had left the study area and the cinnamon teal, a fairly common summer resident of the Piceance

Basin, began appearing in the area. Lower waterfowl usage occurred during early spring rather than late spring. This was probably a result of migrants arriving in the area during April. Spring migrants such as the ring-necked duck, blue-winged teal, and greater yellowlegs were noted during April, but had not appeared by the March censuses.

The blue-winged teal, one of the more common migrants in the Piceance Basin, was less abundant during spring migration than fall migration. During autumn, blue-winged teal commonly congregate in large groups of 30 or more birds, while in the spring the migration groups often consist of single pairs (Johnsgard 1975a).

Between April and June, a slight decrease in total waterfowl utilization occurred on the P.L. Ranch impoundment. Six waterfowl species were recorded in June 1976, and average bird-use day values were lower than in 1975 (Table 3-4-24).

June surveys indicated that the most common nesting species are the mallard, green-winged teal, spotted sandpiper, Wilson's phalarope, and cinnamon teal. Other species that nest in small numbers in the area are the blue-winged teal, American coot, and common snipe. The lesser yellowlegs and solitary sandpiper were recorded in small numbers during July 1976. Neither species is expected to nest on the study area. Both species nest in Canada and Alaska. However, many nonnesting birds remain in Colorado throughout the summer (Bailey and Niedrach 1965). The study area supports a few of these nonnesting individuals during the summer months.

During July 1975, the waterbird utilization of the P.L. Ranch impoundment was dominated by Wilson's phalaropes, green-winged teal, and cinnamon teal. Green-winged teal and killdeer were present in low numbers during July 1976. At the time of the July censuses, males were in their postnuptial molt. At this time males become flightless and are rarely seen (Keith 1961). They may remain in this condition until early fall. Also, during this period many female ducks are still brooding young. Until the juveniles are almost full-grown, the female and her brood generally remain in fairly heavy cover. This would account for the few females observed during the July investigations.

Results from the two-year waterfowl surveys indicated that waterfowl usage along Piceance Creek is fairly high relative to other areas in the Piceance Basin (Rio Blanco Oil Shale Project 1976b, 1976c, 1976d).

3.4.4.5.5 Raptors

Eleven diurnal hawk, vulture, and eagle species, eight owl species, and the common raven have been recorded in the study area (Table 3-4-26). Nests of four of the 20 species have been located in the study area (Table 3-4-26). At least 12 other raptorial species are expected to nest in the region. Four species occur in the study area only during winter months.

Relative abundances were not calculated for diurnal raptor species. Information on seasonal and yearly population trends is based on the collated results of opportunistic sightings made during conduction of other field investigations and the results of nesting surveys.

Seasonal relative abundances were calculated for the nocturnal raptor species observed during the November 1974, December 1975, May 1975, and May 1976 night owl surveys (Table 3-4-27). Limitations in using these indices exist and are related to factors extrinsic to the sampling technique used. Different owl species vary in their nocturnal activity time and in their degree of detectability. For example, the short-eared owl is diurnal as well as nocturnal. The proportion of its time devoted to hunting depends on the availability of preferred foods during the diet cycle (Clark 1975). By contrast, the great horned owl is almost entirely nocturnal (Karalus and Eckert 1974). Varying activity patterns such as these are influential in reducing the confidence one can place in data obtained on the owl night counts.

Fourteen of the 20 raptor species recorded on the study area winter there. Of these 14 species, nine are diurnal raptors. The rough-legged hawk, golden eagle, bald eagle, and common raven are the most abundant diurnal wintering species. The marsh hawk, red-tailed hawk, American kestrel, and prairie falcon have been observed on the study area in small numbers during winter.

Most wintering diurnal species frequented the riparian meadows along Piceance Creek and the bottomland sagebrush and chained pinyon-juniper woodland habitats located throughout the study area. These open areas support abundant small mammal populations during winter. In addition, power lines associated with many of these areas, dead snags in the chained habitat, and pinyon pines and junipers on the adjacent slopes provide many suitable hunting perches and roosts.

According to results of the food habit investigations conducted during March and December 1975, the dominant food items of the wintering marsh hawks, buteos, American kestrels, and common ravens are _Microtus_ sp. and _Peromyscus maniculatus_

Table 3-4-26 RAPTORS NOTED ON THE TRACT C-b STUDY AREA DURING THE 1974-1976 STUDY PERIOD

Species	Occurrence[1]	Status[2]	# of Active Nests Located 1975	1976
Turkey vulture	Summer resident	Uncommon	0	0
Goshawk	Summer resident	Uncertain	0	0
Cooper's hawk	Summer resident	Uncommon	0	0
Sharp-shinned hawk	Summer resident	Uncertain	0	0
Marsh hawk	Permanent resident	Common	0	0
Rough-legged hawk	Winter resident	Common	0	0
Red-tailed hawk	Permanent resident	Common	3	9
Golden eagle	Permanent resident	Common	0	2
Bald eagle	Winter resident	Common	0	0
American kestrel	Permanent resident	Common	0	0
Prairie falcon	Permanent resident	Rare	0	0
Barn owl	Winter resident	Accidental	0	0
Screech owl	Permanent resident	Common	0	0
Great horned owl	Permanent resident	Common	6	6
Long-eared owl	Permanent resident	Uncommon	0	0
Short-eared owl	Permanent resident	Uncommon	0	0
Saw-whet owl	Summer resident	Uncommon	0	0
Snowy owl	Winter resident	Accidental	0	0
Pygmy owl	Summer resident	Uncommon	0	0
Common raven	Permanent resident	Common	2	1
		TOTAL	11	18

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[1] Definitions of terms used to describe occurrence are as follows (based on observations during baseline study, and supplemented where necessary by literature accounts):

Permanent resident: A species present during all seasons

Table 3-4-26 (Continued)

Summer resident: A species present throughout the summer, and assumed to nest in the region
Winter resident: A species present during winter only

[2] Definitions of terms used to describe status are as follows (based on observations during baseline study):

Common: A species noted regularly in its normal habitat at the proper season of the year.
Uncommon: A species of regular occurrence in small numbers, at the proper season of the year, but not likely to be observed on every census.
Rare: A species present in small numbers, and noted only seldomly in proper habitat.
Accidental: A species which is a casual visitor, and outside its normal range.
Undetermined: A species whose status needs confirmation.

Table 3-4-27 RELATIVE ABUNDANCE OF OWL SPECIES RECORDED ON TRACT C-b DURING 1974-1976

Species	November 1974		December 1975		May 1975		May 1976[3]	
	Number Recorded	% R. A.[1]	Number Recorded	% R. A.	Number Recorded	% R. A.	Number Recorded	% R. A.
Barn owl	1	14.2	--	--	--	--	--	--
Great horned owl	2	28.6	34	92.0	17	73.9	4	26.7
Screech owl	2	28.6	1	2.6	4	17.4	5	33.3
Long-eared owl	2	28.6	1	2.6	--	--	2	13.3
Short-eared owl	--[2]	--	1	2.6	--	--	1	6.1
Saw-whet owl	--	--	--	--	2	8.7	2	13.3
Pygmy owl	--	--	--	--	--	--	1	6.7
TOTAL	7	100.0	37	100.0	23	100.0	15	100.0

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[1] % Relative abundance was calculated as follows:

$$\%\ \text{R. A.} = \frac{\text{Total number of individuals of species A}}{\text{Total number of all species}} \times 100\%$$

[2] = not recorded during survey

[3] During May 1976 the night owl count was conducted once due to inclement weather.

(Table 3-4-28). The abundance of these small mammals is probably the major limiting factor on the size of these diurnal raptor species. Galushin (1974) noted that many northern raptors show marked annual fluctuations in numbers in response to oscillations in rodent numbers.

Although no winter pellets of the bald eagle and golden eagle were collected, these birds apparently feed predominately on mule deer carrion and lagomorphs during the winter. The common raven also scavenges on carrion. The bald eagle and common raven were generally associated with golden eagles during the winter months. It was not unusual to observe golden eagles, bald eagles, and common ravens sharing roosts and deer carcasses.

Fluctuations in winter mule deer and lagomorph populations may induce wide-ranging species such as the golden eagle and bald eagle to expand their winter range. The size of these raptors' wintering range is dependent on prey density (Brown and Amadon 1968). During harsh winters, local eagle populations may expand their winter range and not be noticed as frequently on the study area. This is exemplified by the fewer number of eagles observed in the study area during the harsher 1974-1975 winter in comparison with the milder 1975-1976 winter.

Rough-legged hawks began appearing on the area during November and had left the area by March. Davis (1969) reported this species as an uncommon winter visitor in western Colorado. Generally, the presence of these birds indicates high population of small rodents, which comprise the majority of this species' diet (Craighead and Craighead 1969). The lower number of this species on the study area during the 1975-1976 winter may have been attributed to lower winter small rodent populations on the study area in comparison with the 1974-1975 winter. Its lower winter population may have also been attributed to factors influencing the population on the breeding range. A mild winter may have occurred in Canada and Alaska as it did in the Piceance Basin during 1974-1975, and many rough-legged hawks may have overwintered in their breeding range. This is common, particularly during years of abundant lemming populations. The lemming is a preferred food item of the rough-legged hawk on its arctic breeding grounds (Brown and Amadon 1968).

Although common during the summer and fall, the American kestrel, marsh hawk, and red-tailed hawk are not abundant on the study area during late winter. During the late summer and fall, red-tailed hawks, marsh hawks, and American kestrels were observed frequently hunting over the newly-plowed riparian meadows along Piceance Creek. The plowing made the resident small mammals and grasshoppers more vulnerable to predation, causing raptors to concentrate in the area.

Table 3-4-28 SUMMARY OF RAPTOR PELLET ANALYSIS 1975-1976, TRACT C-b SHALE OIL PROJECT

Raptor Species	Prey Species Represented	March 1975		May 1975		October 1975		December 1975		April 1976		July 1976	
		# of Prey Species[1]	% R.A.2	# of Prey Species	% R.A.	# of Prey Species	% R.A.	# of Prey Species	% R.A.	# of Prey Species	% R.A.	# of Prey Species	R.A.
Marsh hawk	*Microtus* sp.	3	100.0	--***	--	--	--	--	--	--	--	--	--
		3	100.0	0	100.0	0	100.0	0	100.0	0	0.0	0	0.0
Red-tailed hawk	*Peromyscus maniculatus*	--	--	--	--	1	100.0	--	--	--	--	3	25.0
	Thomomys talpoides	--	--	--	--	--	--	--	--	--	--	1	8.3
	Unidentified lagomorphs	--	--	--	--	--	--	--	--	--	--	7	58.3
	Unidentified birds	--	--	--	--	--	--	--	--	--	--	1	8.3
		0	0.0	0	0.0	1	100.0	0	0.0	0	0.0	12	100.0
Buteo sp.[3]	*Microtus* sp.	60	91.0	--	--	--	--	2	66.6	4	50.0	--	--
	Peromyscus maniculatus	3	4.5	--	--	--	--	--	--	--	--	--	--
	Thomomys talpoides	1	1.5	--	--	--	--	--	--	2	25.0	--	--
	Lepus sp.	1	1.5	--	--	--	--	--	--	--	--	--	--
	Unidentified lagomorphs	--	--	--	--	--	--	--	--	2	25.0	--	--
	Unidentified birds	1	1.5	--	--	--	--	1	33.3	--	--	--	--
		66	100.0	0	0.0	0	0	3	100.0	8	100.0	0	0.0

Table 3-4-28 (Continued)

Raptor Species	Prey Species Represented	March 1975 # of Prey Species	March 1975 % R.A.	May 1975 # of Prey Species	May 1975 % R.A.	October 1975 # of Prey Species	October 1975 % R.A.	December 1975 # of Prey Species	December 1975 % R.A.	April 1976 # of Prey Species	April 1976 % R.A.	July 1976 # of Prey Species	July 1976 R.A.
Golden eagle	*Odocoileus hemionus*	--	--	--	--	--	--	--	--	--	--	5	4.6
	Lepus sp.	--	--	--	--	--	--	--	--	--	--	17 4/	15.7
	Unidentified lagomorphs	--	--	--	--	--	--	--	--	--	--	21	19.4
	Mustella frenata	--	--	--	--	--	--	--	--	--	--	1	1.0
	Ondatra sp.	--	--	--	--	--	--	--	--	--	--	4	3.7
	Eutamias sp.	--	--	--	--	--	--	--	--	--	--	2	1.9
	Neotoma sp.	--	--	--	--	--	--	--	--	--	--	1	1.0
	Peromyscus maniculatus	--	--	--	--	--	--	--	--	--	--	4	3.7
	Thomomys talpoides	--	--	--	--	--	--	--	--	--	--	4	3.7
	Unidentified mammals	--	--	--	--	--	--	--	--	--	--	14	12.9
	Unidentified birds	--	--	--	--	--	--	--	--	--	--	17	15.7
	Invertebrates	--	--	--	--	--	--	--	--	--	--	1	1.0
	Plant material	--	--	--	--	--	--	--	--	--	--	17	15.7
		0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	108	100.0
American kestrel	*Microtus* sp.	1	50.0	--	--	--	--	--	--	1	25.0	--	--
	Peromyscus maniculatus	1	50.0	--	--	--	--	--	--	--	--	--	--
	Thomomys talpoides	--	--	--	--	--	--	--	--	1	25.0	--	--
	Unidentified mammals	--	--	--	--	--	--	--	--	1	25.0	--	--
	Invertebrates	--	--	--	--	12	100.0	--	--	--	--	--	--
	Plant material	--	--	--	--	--	--	--	--	1	25.0	--	--
		2	100.0	0	0.0	12	100.0	0	0.0	4	100.0	0	0.0

Table 3-4-28 (Continued)

Raptor Species	Prey Species Represented	March 1975 # of Prey Species	March 1975 % R.A.	May 1975 # of Prey Species	May 1975 % R.A.	October 1975 # of Prey Species	October 1975 % R.A.	December 1975 # of Prey Species	December 1975 % R.A.	April 1976 # of Prey Species	April 1976 % R.A.	July 1976 # of Prey Species	July 1976 % R.A.
Great horned owl	*Microtus* sp.	272	93.1	102	54.8	10	83.3	15	60.0	8	28.6	15	20.0
	Peromyscus maniculatus	6	2.1	35	18.8	--	--	--	--	2	7.1	7	9.3
	Thomomys talpoides	7	2.4	36	19.4	2	16.7	6	24.0	12	42.9	27	36.0
	Lepus sp.	1	<1.0	--	--	--	--	--	--	--	--	--	--
	Sylvilagus sp.	1	<1.0	3	1.6	--	--	--	--	--	--	19	25.3
	Unidentified lagomorphs	--	--	--	--	--	--	4	16.0	5	17.8	--	--
	Lagurus curtatus	--	--	6	3.2	--	--	--	--	--	--	--	--
	Neotoma sp.	--	--	3	1.6	--	--	--	--	--	--	3	4.0
	Sorex sp.	--	--	1	<1.0	--	--	--	--	1	3.6	--	--
	Unidentified mammals	2	<1.0	--	--	--	--	--	--	--	--	--	--
	Unidentified birds	--	--	--	--	--	--	--	--	--	--	4	5.3
	Invertebrates	3	1.0	--	--	--	--	--	--	--	--	--	--
		292	100.0	186	100.0	12	100.0	25	100.0	28	100.0	75	100.0
Common raven	*Microtus* sp.	47	70.1	5	100.0	42	49.4	5	83.3	--	--	--	--
	Peromyscus maniculatus	--	--	--	--	6	7.1	--	--	--	--	--	--
	Thomomys talpoides	2	3.0	--	--	2	2.3	--	--	--	--	5	10.6
	Neotoma sp.	1	1.5	--	--	--	--	--	--	--	--	--	--
	Sylvilagus sp.	--	--	--	--	1	1.2	1	16.6	--	--	--	--
	Unidentified lagomorphs	--	--	--	--	--	--	--	--	--	--	2	4.3
	Unidentified mammal[5]	--	--	--	--	--	--	--	--	--	--	19	40.4
	Invertebrates	5	7.5	--	--	34	40.0	--	--	--	--	8	17.0
	Plant material	7	10.4	--	--	--	--	--	--	--	--	--	--
	Inorganic (rocks, dirt)	5	7.5	--	--	--	--	--	--	--	--	13	27.7
		67	100.0	5	100.0	85	100.0	6	100.0	0	0.0	47	100.0

Table 3-4-28 (Concluded)

Raptor Species	Prey Species Represented	March 1975 # of Prey Species	March 1975 % R.A.	May 1975 # of Prey Species	May 1975 % R.A.	October 1975 # of Prey Species	October 1975 % R.A.	December 1975 # of Prey Species	December 1975 % R.A.	April 1976 # of Prey Species	April 1976 % R.A.	July 1976 # of Prey Species	July 1976 % R.A.
Unidentified raptor sp.	*Microtus* sp.	--	--	--	--	1	50.0	--	--	--	--	--	--
	Thomomys talpoides	--	--	--	--	1	50.0	--	--	--	--	--	--
		0	0.0	0	0.0	2	100.0	0	0.0	0	0.0	0	0.0

[1] Number of prey species is based on frequency of occurrence of prey species in the pellets.

[2] $\% \text{ Relative Abundance} = \frac{\text{Number of individuals of species A}}{\Sigma \text{ number individuals of all species}} \times 100$

[3] During periods when both rough-legged hawks and red-tailed hawks were observed utilizing the study area, the pellets were only identified to *Buteo* sp.

[4] *Lepus* sp. was represented by 17 feet, not pellets.

[5] The unidentified mammal remains were thought to be lagomorph, but identification was not positive due to poor condition of bone material.

Although the red-tailed hawk and marsh hawk both prey on vole populations in the meadows, no interspecific competition was witnessed. A hunting tolerance seemed to exist which allowed both species to hunt within an area if enough food was available. When food availability was low, some, if not all, of the individuals probably moved to other hunting areas. If few rough-legged hawks entered the study area, a few red-tailed hawks and marsh hawks would overwinter in riparian meadow habitats on the study area. This was noted during the winter of 1975-1976. However, during winters when rough-legged hawks are more abundant and are exerting pressure on a low winter vole population, the local red-tailed hawks and marsh hawks do not remain in the study area beyond early winter. This condition was observed on the study area during the 1974-1975 winter.

The American kestrel population decreases between fall and winter as insect populations decline. Grasshoppers and beetles are the dominant food source of this species during fall (Table 3-4-28). The few that overwinter in the area feed primarily on Microtus sp. and Peromyscus mainculatus (Table 3-4-28). The number of American kestrels on the study area during winter is probably dependent on the number of other diurnal raptor species present and the abundance of small mammals.

Of the eight owl species recorded, six species winter in the area. During November 1974, the great horned owl (28.6 percent R.A.), screech owl (28.6 percent R.A.), long-eared owl (28.6 percent R.A.), and barn owl (14.2 percent R.A.) were recorded in small numbers (Table 3-4-27).

The barn owl is an unusual visitor to this portion of Colorado, and few records exist. A single individual was observed on a fence post near the Tract. The distribution of home dwellings along Piceance Creek and the barn owl's preference for such habitation may account in part for its presence.

A snowy owl was recorded on the Tract during the 1974-1975 winter. Two records of snowy owls have been noted in the literature for northwestern Colorado. The presence of this species in southern temperate regions usually coincides with cyclic population patterns exhibited in its arctic breeding area. Peak owl populations coupled with dramatic declines in prey populations produce periodic winter "invasions" of snowy owls into the United States.

During December 1975 an average of 16.5 great horned owls were recorded per night during the two-night owl survey (Table 3-4-27). The large number of great horned owls recorded during this survey, in comparison with the November 1974 survey, is related to the initiation of their breeding season. Mating calls begin in earnest, generally in late December and early January

(Karalus and Eckert 1974), making them more detectable at this time.

Screech owls (2.6 percent R.A.), long-eared owls (2.6 percent R.A.), and short-eared owls (2.6 percent R.A.) were also recorded in small numbers during December 1975.

The owl species noted during one or both winters were generally recorded in areas where they were active during summer. This indicates that overwintering owls probably remain near their nesting territory. Seasonal migrations within the study area do not appear to occur. The owls either overwinter in their summer ranges, or migrate out of the area during severe winters. The species' ability to withstand the winter is probably dependent on its hardiness and the availability of the prey populations. The great horned owl, screech owl, and long-eared owl were the only species noted on the study area during both winters. These three species generally do not migrate. The absence of the short-eared owl during the 1975-1976 winter is probably directly related to the severity of that winter. The absence of the screech owl during the 1974-75 winter indicates that this species apparently migrates from the study area on an irregular basis, depending on winter weather and food availability.

Any attempt at describing the distribution and abundance of winter owl populations on the study area is limited, since few observations of this elusive nocturnal group occurred outside of the nocturnal counts. Owl species residing on the study area during winter are probably more abundant and more widely distributed than the data indicate.

By March of both years the wintering bald eagles and rough-legged hawks had left the area. The common ravens and golden eagles that nest on the study area initiated nesting activity during March. This information is based on the age of the nestlings found in the nests of both species, during the nest surveys conducted on the study area and in other parts of the Piceance Basin. Egg laying generally begins between mid-February and the end of March for Rocky Mountain golden eagles (Camenzind 1969, Snow 1973). Common ravens in the Rocky Mountain region are known to select nesting territories in early March (Craighead and Craighead 1969).

By April, the majority of the study area's diurnal breeding raptors are present. Red-tailed hawks, marsh hawks, and American kestrels are present in greater numbers than during the winter and goshawks, Cooper's hawks, sharp-shinned hawks, and turkey vultures have arrived.

Six owl species were recorded during the two May road counts (Table 3-4-27). The great horned owl (74.2 percent R.A., 1975; 26.7 percent R.A., 1976) and screech owl (17.0 percent R.A., 1975; 33.3 percent R.A., 1976) were the most abundant species. The long-eared owl, short-eared owl, saw-whet owl, and pygmy owl were also recorded in small numbers.

Nesting raptors range throughout the study area. The pinyon-juniper woodland habitat provides abundant nesting areas for the American kestrel, red-tailed hawk, Cooper's hawk, sharp-shinned hawk, great horned owl, saw-whet owl, long-eared owl, screech owl, and pygmy owl. One active red-tailed hawk nest, one active golden eagle nest, and one inactive raptor nest have been located in this habitat type on the study area.

The rimrock located throughout the study area provides potential nest sites for golden eagles, red-tailed hawks, American kestrels, prairie falcons, great horned owls, long-eared owls, turkey vultures, and common ravens. To date, one active golden eagle nest, eight active great horned owl nests, eight active red-tailed hawk nests, two active common raven nests, and twenty inactive nests have been located in the rimrock area located throughout the study area.

The marsh hawk and screech owl are the only ground-nesting species on the study area and are distributed in the brushland and riparian meadow habitats located throughout the study area. No nests of these species have been located in the study area.

Summer food habit studies indicate that the important raptor food items during the breeding season are Microtus sp., lagomorphs, Thomomys talpoides, and Peromyscus maniculatus (Table 3-4-28).

3.4.4.5.6 Habitat Requirements of Principal Species

The important songbird species have been defined as those breeding species with the two highest importance values. These species are the broad-tailed hummingbird, mountain bluebird, hermit thrush, blue-gray gnatcatcher, red-winged blackbird, green-tailed towhee, gray-headed junco, chipping sparrow, vesper sparrow, and song sparrow.

The mourning dove is an important Tract species due to its status as the most common gamebird in the area. Similarly, the mallard and green-winged teal have been identified as important because they are the most abundant year-round waterfowl residents on the study area.

Raptor species are important to the Tract C-b area because they aid in maintaining a balanced ecosystem by regulating the local prey population. The species most effective at regulating prey populations throughout the Tract C-b area are the abundant raptor species present on the study area throughout the year. These are the golden eagle, red-tailed hawk, American kestrel, great horned owl, and common raven. These five species are considered the "important" raptor species on the study area.

In addition, the greater sandhill crane is listed as an important species because of its status as an endangered species.

A brief listing of the habitat requirements for the above-mentioned important species is presented in Table 3-4-29.

3.4.5 Amphibians and Reptiles

3.4.5.1 Rationale

Although reptiles and amphibians were not abundant or widely distributed in the study area, they are important consumers of insects and therefore represent a link in the terrestrial food chain. As part of the functioning ecosystem it is therefore necessary to adequately describe population characteristics of this group.

3.4.5.2 Objectives

To adequately describe the importance of the reptiles and amphibians, studies were designed to determine the species present, their distribution,and their relative abundance.

3.4.5.3 Experimental Design

Sampling was conducted on small mammal Grids 1 and 2 during the months between May-September in 1975 and 1976. This period corresponded to the active season for reptiles in this geographic area when relative abundance is most easily obtained. During sampling periods in spring and early summer, the months when juveniles from spring clutches disperse, special observations were made on the size of captured individuals which gave an index to age class structure for the population.

Table 3-4-29 HABITAT REQUIREMENTS OF IMPORTANT BIRD SPECIES ON TRACT C-b

Species	Seasonal Status[1]	Preferred Habitat on Tract C-b[2]	Preferred Nest Location(s)	Diet Preferences	Comments
Broad-tailed hummingbird	SR	6	brush & trees, above ground	flower nectar, invertebrates	Distributed throughout study area
Mountain bluebird	SR	5	cavities	insects	Distributed throughout study area
Hermit thrush	SR	4	trees	insects	
Blue-gray gnatcatcher	SR	3,9	bushes, above ground	arthropods	Some nesting in pinyon-juniper woodland
Red-winged blackbird	PR	2	cattails, wet meadows	arthropods, grains	Colonial nesting species in marshy habitat
Green-tailed towhee	SR	1,6,9	bushes, ground-nesting	omnivorous	Abundant in brushlands
Gray-headed junco	PR	4	ground-nesting	seeds	Common throughout area in winter
Chipping sparrow	SR	4,5,8	bushes, small trees	omnivorous	
Brewer's sparrow	SR	1,3,7	bushes, near ground	omnivorous	
Vesper sparrow	SR	3,7,8	ground-nesting	omnivorous	
Song sparrow	PR	2	ground-nesting, bushes above ground	omnivorous	Prefers water's edge vegetation
Mourning dove	SR	4,8	ground, shrubs, trees	herbivorous	An important game species that nests, to some extent, throughout the study area
Mallard	PR	2	dry brushy areas near streams, ponds	aquatic vegetation, grain crops	The most abundant year-round waterfowl on the study area
Green-winged teal	PR	2	dry hillsides, brushy areas near ponds		
Golden eagle	PR	10	cliff areas, large trees	carrion, lagomorphs, rodents	Availability of suitable nests is probably the limiting factor on breeding population

Table 3-4-29 (Continued)

Species	Seasonal Status[1]	Preferred Habitat on Tract C-b [2]	Preferred Nest Location (s)	Diet Preferences	Comments
Red-tailed hawk	PR	10	cliff areas, trees	rodents	Probably most common raptor on study site
Great-horned owl	PR	10	cliff areas, trees	rodents, small vertebrates	Abundant year-round resident
American kestrel	PR	4,6,7	cavities in trees, cliff areas	insects, small rodents	
Common raven	PR	10	cliff areas	carrion	
Greater sandhill crane	M	2	creeks, marshy areas with suitable nesting cover	succulent plants, wild rye, invertebrates	Currently not nesting in Piceance Basin but appears during spring and fall migration

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[1] Definitions of terms used to describe seasonal status are as follows (based on observations during baseline study, and supplemented where necessary by literature accounts):

PR - Permanent resident: A species present during all seasons
SR - Summer resident: A species present throughout the summer, and assumed to nest in the region
M - Migrant: A species present only on a migratory (short term) basis

[2] Number notations correspond to habitats as follows (based on observations during baseline study):

1 - Chained pinyon-juniper woodland
2 - Riparian meadow
3 - Bottomland sagebrush
4 - Pinyon-juniper woodland
5 - Pinyon-juniper/mixed brush
6 - Canyon sagebrush
7 - Upland sagebrush
8 - Upland transition
9 - Mixed mountain shrub
10 - Wide-ranging, throughout Tract C-b

3.4.5.4 Brief Methodological Description

The relative abundance of reptile species on small mammal Grids 1 and 2 was estimated from line transect counts described in Appendix IV-A. Ten transects, 150 meters in length, were surveyed on each grid.

Identification of reptile and amphibian species not observed on Grids 1 and 2 and the distribution of species over the range of habitats represented in the study area were determined by opportunistic observations made during the course of related studies. The nomenclature used follows Stebbins (1966).

3.4.5.5 Results and Discussion

3.4.5.5.1 Species Composition

A greater number of reptile species was observed on Grid 1 (four) than on Grid 2 (one). This difference in species composition was consistent throughout the study and may be related to habitat structure which varied between the two grids. The sagebrush lizard, Sceloporus graciosus, was abundant on both grids and was widespread in its distribution on Tract C-b. Slash piles and increased grass cover were apparently responsible for the additional species, i.e., the northern plateau lizard, Sceloporus undulatus elongatus, the tree lizard, Urosaurus ornatus, and the short horned lizard, Phrynosoma douglassi, present on Grid 1.

Observations over the entire Tract revealed one additional reptile, the western terrestrial garter snake, Thamnophis elegans, and two amphibians, the Utah tiger salamander, Ambystoma tigrinum utahensis, and the leopard frog, Rana pipiens. Only the leopard frog was commonly observed and appeared to be the most abundant amphibian in the study area. Large numbers were observed in Lower Stewart Lake, Lower Stewart Creek, and Piceance Creek. They were frequently observed at distances up to 100 meters from permanent creeks and springs when hay meadows were flooded. Movement away from permanent water bodies is most often related to foraging activities (Stebbins 1966). Other species expected in the study area but not observed included the western rattlesnake, Crotalus viridis, and the gopher snake, Pituophis melanoeucus.

3.4.5.5.2 Relative Abundance of Reptiles on Small Mammal Grids 1 and 2

The sagebrush lizard was the most abundant reptile on both grids while the northern plateau lizard, tree lizard, and short horned lizard were observed only on Grid 1 and were less abundant than the sagebrush lizard (Table 3-4-30). The relative abundances

Table 3-4-30 RELATIVE ABUNDANCE[1] OF REPTILES ON GRIDS 1 (CHAINED PINYON-JUNIPER RANGELAND) AND 2 (PINYON-JUNIPER WOODLAND) FROM JUNE 1975 - AUGUST 1976

Scientific Name/Common Name	June 1975		July 1975		August 1975		September 1975		June 1976		July 1976		August 1976	
	Grid 1	Grid 2	Grid 1	Grid 2	Grid 1	Grid 2	Grid 1	Grid 2	Grid 1	Grid 2	Grid 1	Grid 2	Grid 1	Grid 2
Sceloporus graciosus Sagebrush lizard	4	3	5	9	6.33	3	.33	.33	16	14.33	18.66	9.66	13.33	7
Sceloporus undulatus elongatus Northern plateau lizard	.66		1		1				6		4.66		.66	
Urosaurus ornatus Tree lizard					.33		.33		.66		.33		.66	
Phrynosoma douglassi Short-horned lizard	.66								.33		.33		.33	

[1] Relative abundance = the mean number of individuals observed on Grids 1 and 2 during 2-hour line transect counts, where the mean number of individuals = $\frac{\text{Total number of individuals observed during three consecutive daily line transect counts}}{3}$.

reported represent the mean number of individuals observed per day during the three-day sample periods, and may not reflect the true abundance of lizards on each grid. Mark and recapture procedures which were implemented during 1975 indicated that less than 2 percent of animals marked during three-day sample periods were recaptured. Based upon these results it is apparent that densities of lizards on Grids 1 and 2 may have been much higher than the number observed each day and may also have been significantly higher than the total number of individuals observed during each three-day sampling period.

Poor recapture success may have been due to immigration of transient individuals rather than large numbers of resident lizards. Previous studies (Stevens 1973) have shown that although sagebrush lizards occupy a home range and defend a territory they will demonstrate considerable tolerance of immigrating individuals. It is therefore possible that a significant percentage of lizards marked and not recaptured represent transient individuals that should not be considered a part of the resident population.

Annual fluctuations of relative abundance are also apparent from line transect counts (Table 3-4-30). The relative abundance of the two most abundant lizards, the sagebrush lizard and the northern plateau lizard, was appreciably higher in 1976 than their relative abundance during 1975. A majority of this increase can be attributed to juveniles (one to four months old) from spring clutches that became active in late spring-early summer. Juveniles were numerous in the June-August sampling period and accounted for approximately 50-60 percent of the total number of individuals. The successful spring reproductive effort for reptiles may be attributed to the same factors which affected small mammal reproduction, i.e., mild weather and abundant food resources. Insects, spiders, mites, and other arthropods which serve as food supply were plentiful throughout the spring and early summer.

3.4.5.5.3 Turnover and Longevity

Various turnover rates, the percentage of adult lizards which survive the winter season, have been reported for the sagebrush lizard: 36 percent (Stevens 1973) and 60 percent (Stebbins 1948). Fitch (1940) and Stebbins (1944) identified winter mortality as the most significant factor in population loss. Due to the relative length and severity of the winter season in the Piceance Creek basin, winter loss may be much higher than these figures for Tract C-b with turnover rate estimated at 10-20 percent.

3.4.5.5.4 Food Habits

Lizards of the genus Sceloporus generally feed on a wide variety of insects and arachnids (Tolliver and Jennings 1975). Stomach content analysis of 2,191 sagebrush lizards collected over a 16-year period in Utah yielded 24,000 identifiable insects and terrestrial arthropods. Hymenoptera, Hemiptera, and Coleoptera were important food items numerically. The occurrence of large numbers of specific food items indicated that both species may be opportunistic feeders and may exhibit pronounced seasonal variation in their prey selection.

The mountain short horned lizard also feeds on a variety of insects, insect larvae, and snails if available. The tree lizard is a predator of insects and spiders.

3.4.6 Terrestrial Invertebrates

3.4.6.1 Rationale

Arthropods are an integral part of most terrestrial communities. They are preyed upon by insectivorous consumers and also function as herbivores, predators, and scavengers. During periods of maximum abundance, arthropods are often a major consumer of primary productivity (Furniss and Barr 1975, Mitchell and Pfadt 1974), and may compete with cattle and wildlife for food resources. Many arthropods also function as pollinators and are critical to the successful reproduction of native vegetation as well as commercial crops.

To adequately describe the arthropod community on Tract C-b, several parameters were selected for study based upon the following considerations: 1) parameters were chosen that are commonly evaluated in similar research and therefore could be compared to results in the literature; 2) to satisfy conditions of the lease which stipulates that studies shall determine the species present, their distribution, their relative abundance, and plant-insect relationships; and 3) to evaluate these parameters which could be included in a long-term monitoring program.

3.4.6.2 Objectives

The objectives of arthropod studies were: 1) to determine the species composition and trophic level of ground dwelling and arboreal arthropods; 2) to determine the relative abundance of arthropods in the two major habitat types (pinyon-juniper and chained pinyon-juniper); 3) to describe seasonal relative abundance; and 4) to determine insect-host plant relationships for the important native shrubs on Tract C-b.

3.4.6.3 Experimental Design

Ground arthropods and shrub dwelling arthropods were sampled on small mammal Grids 1 and 2. These two grids represented chained pinyon-juniper rangeland and pinyon-juniper woodland which together comprised 85 percent of the total study area. Remaining habitat types were not sampled because it was felt that a representative estimate of arthropod species diversity and relative abundance for the study area could be obtained in these two major habitats. Aquatic invertebrates were a major group not sampled in these studies and are discussed in the Aquatic Biology Section.

Sampling was conducted during the small mammal trapping period, May-September, which corresponds to the season of major activity for arthropods on Tract C-b. Cold temperatures and lack of food resources prevent the expansion of arthropod populations during the remaining portion of the year (October-April) in this geographic area.

3.4.6.4 Brief Methodological Description

Ground arthropods were collected from pitfalls, spaced 15 meters apart on 7x7 grids and located on small mammal Grids 1 and 2 (Appendix IV-A). Pitfalls were inspected every 48 hours. Captured arthropods were preserved in alcohol and transported to the laboratory for identification. The nomenclature used follows Borrer and DeLong (1971).

Shrub dwelling arthropods were collected from three species of shrubs which were most heavily browsed by mule deer: mountain mahogany, serviceberry, and big sagebrush. Shrubs were sampled by beating branches to dislodge arboreal insects. This beating caused the insects to drop into a net held beneath the shrubs.

Total number of individuals, species diversity, and number of individuals per trophic level were compared between shrub species, seasons, and sample locations.

3.4.6.5 Results and Discussion

3.4.6.5.1 Ground Dwelling Arthropods

3.4.6.5.1.1 Species Composition and Relative Abundance

Darkling beetles (Tenebrionidae), ants (Formicidae), mites (Acari), hunting spiders (Gnaphosidae), wolf spiders (Lycosidae), ground beetles (Carabidae) and Jerusalem crickets (Gryllacrididae) were the most abundant arthropods on Grids 1 and 2 (Appendix IV-B, Tables B-4-23 and B-4-24).

Darkling beetles were very abundant on both grids, as they are throughout arid habitats in the western United States (Borer and Delong 1971). Mites were abundant seasonally, during August-September, and were most abundant on Grid 2. Ants were the most abundant group of all arthropods collected and were abundant on both grids. Several families of spiders were common on both grids and were captured most often near areas where the herbaceous layer was well developed.

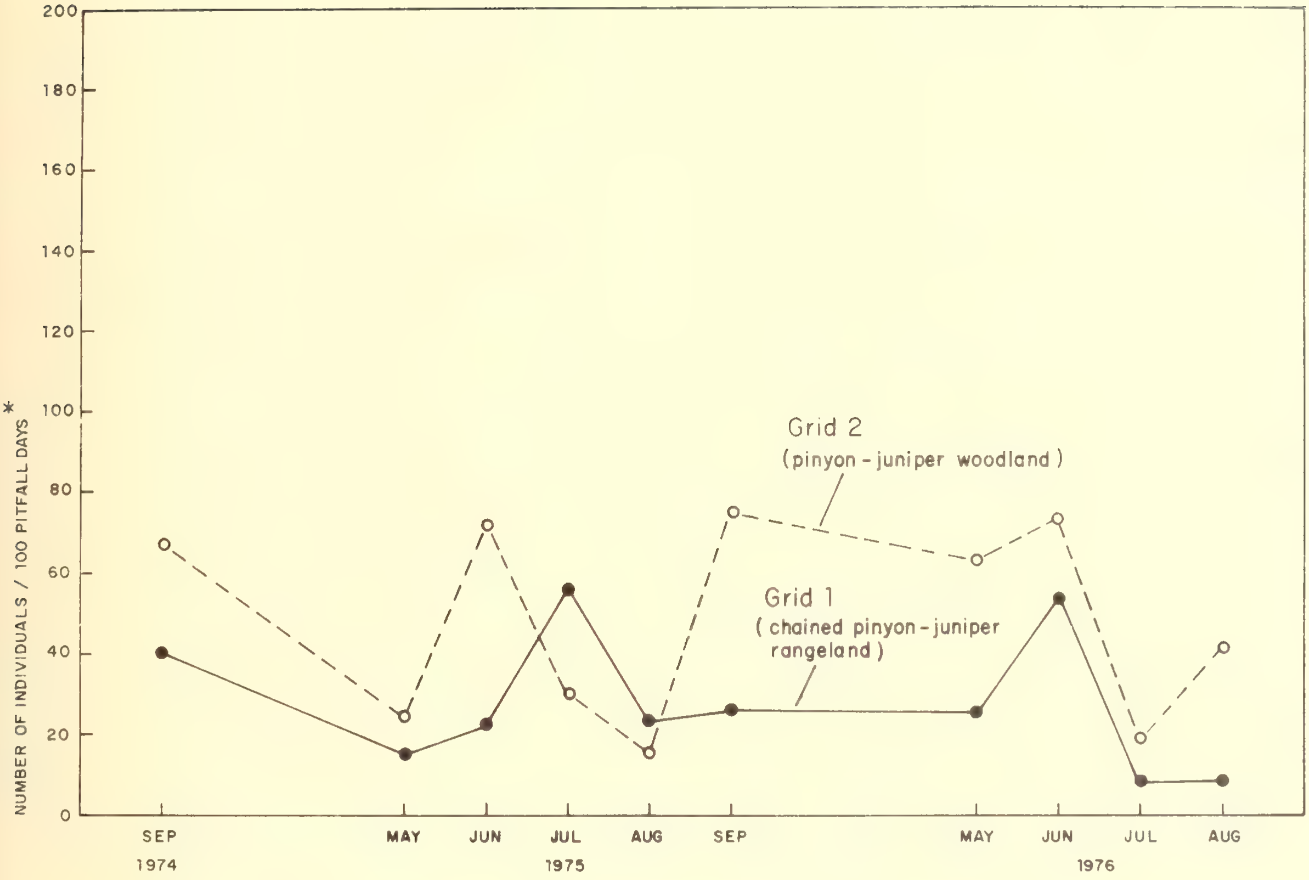
The total number of individuals captured per 100 pit can days was highest on Grid 2 (pinyon-juniper woodland) in all but two months during the period August 1974-August 1976 (Figure 3-4-16). However, examination of the number of individuals captured for each species (Appendix IV-B, Table B-4-24), shows that the majority of arthropods collected on Grid 2 consisted of one or two species captured in great abundance, i.e., ants and mites. In many months the number of ants or mites collected was extremely high and often totaled more than all other species combined. As a result, data graphed as the total number of individuals is more a representation of the total number of ants and mites and may not reflect the importance of other groups of insects which are less numerous.

To account for the number of species as well as the distribution of individuals among species, the Shannon-Wiener measure of species diversity was used to compare the diversity of arthropods on Grids 1 and 2 (Figure 3-4-17). The results show that although Grid 2 had a higher number of individuals during most months, Grid 1 showed a significantly higher arthropod diversity in all but two months (Appendix IV-B, Tables B-4-25 and B-4-26).

Diverse communities generally result from: 1) a greater range of available resources; and/or 2) their component species may exploit only a small range of the available resources. Higher arthropod species diversity on Grid 1 (chained pinyon-juniper) may have resulted from the greater range of available resources provided by the slash piles and increased herbaceous vegetation created by the chaining operation. The presence of seven different families of Hemipterans, all of which are phytophagus, on Grid 1 may reflect the greater range of vegetation present and was apparently responsible for higher species diversity.

3.4.6.5.1.2 Trophic Structure Analysis

The most numerous species on Grids 1 and 2 were assigned to three major trophic levels -- omnivores, predators, and scavengers -- (Figure 3-4-18) based upon trophic level designations by Ellis and French (1973). Omnivores were the dominant group of ground dwelling arthropods on Grid 2. Ants comprised the majority



* One pitfall day represents one pitfall operated for 24 hours.

Figure 3-4-16
RELATIVE ABUNDANCE OF ARTHROPODS COLLECTED
FROM PITFALLS LOCATED ON GRIDS 1 AND 2.

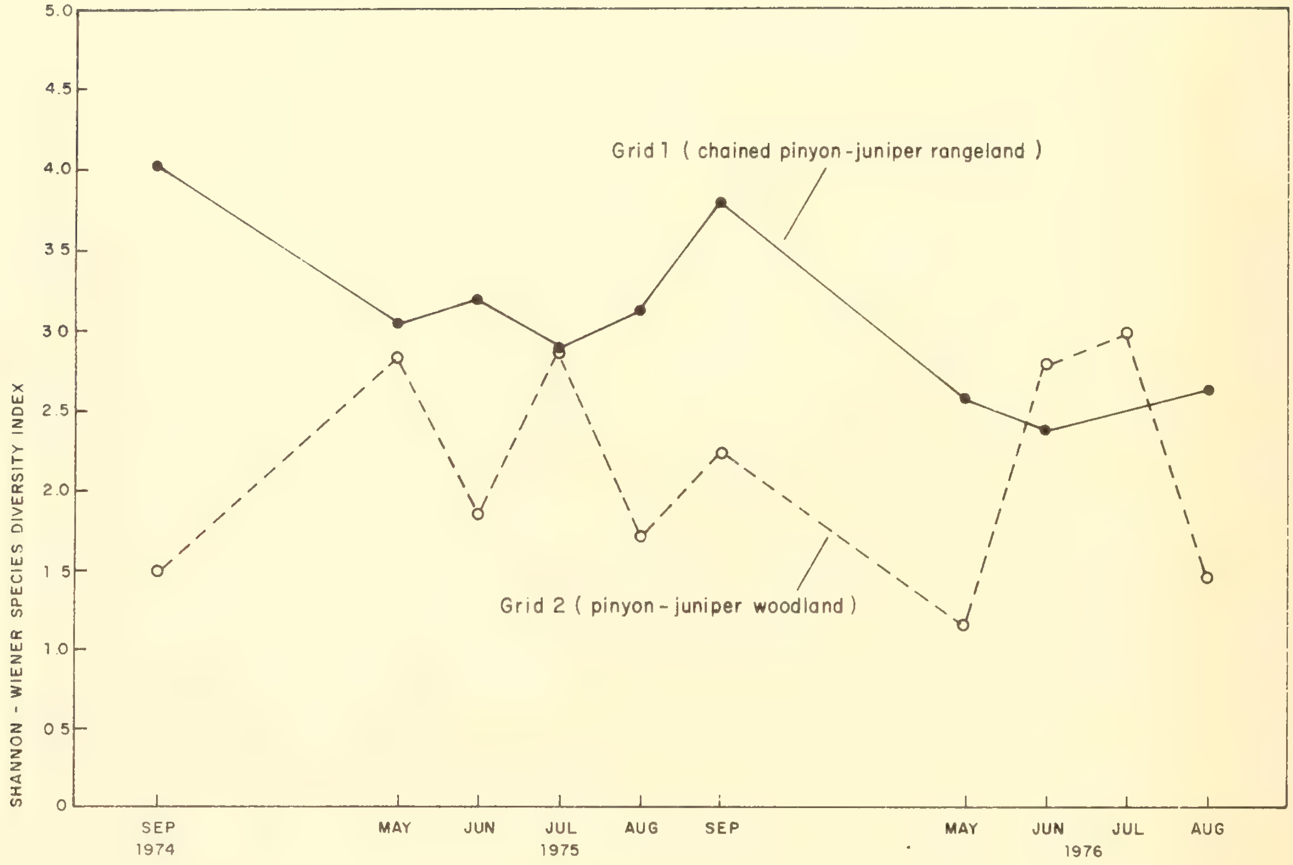
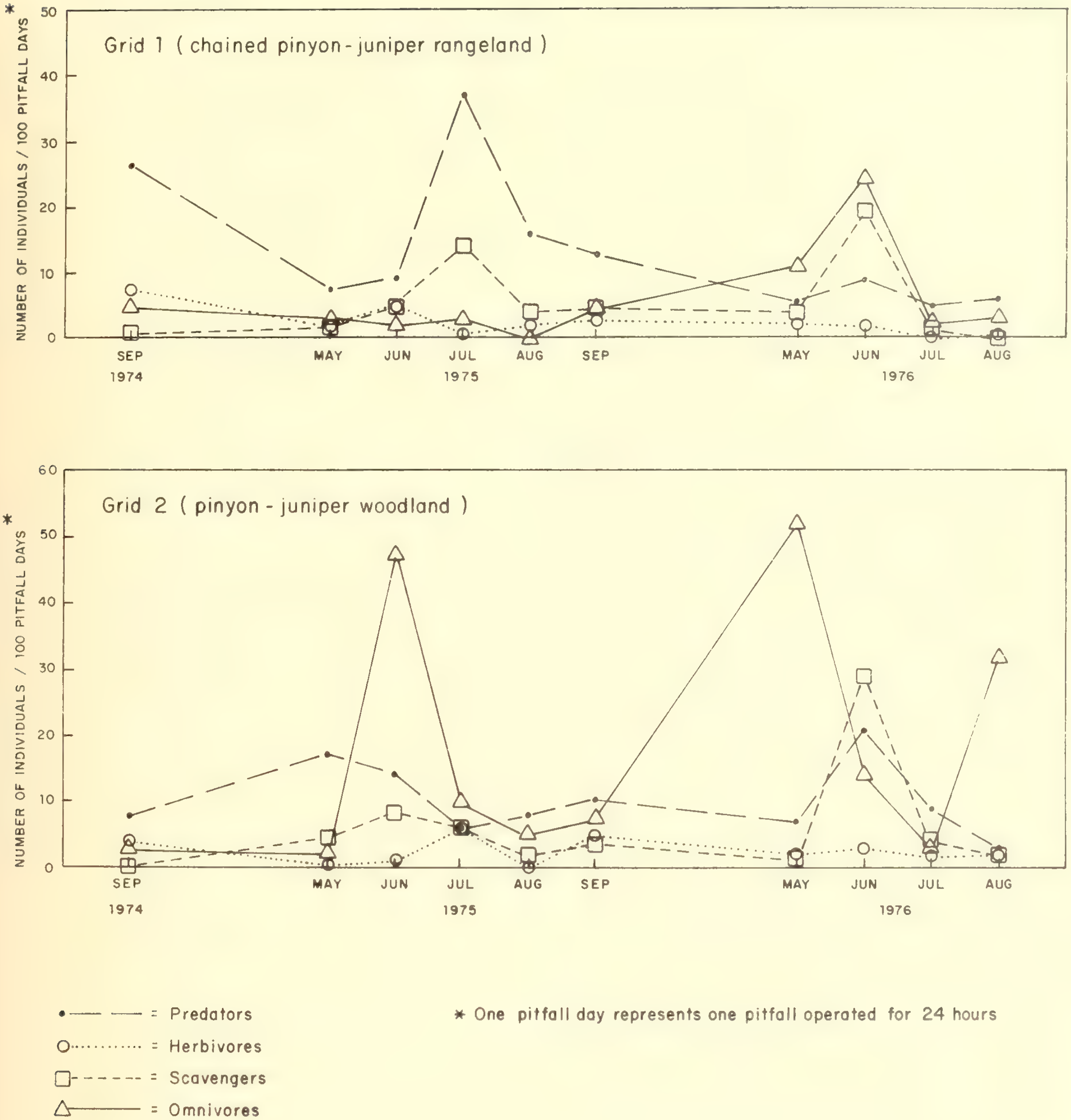


Figure 3-4-17
SPECIES DIVERSITY OF ARTHROPODS COLLECTED FROM PITFALLS LOCATED ON GRIDS 1 AND 2.



* One pitfall day represents one pitfall operated for 24 hours

Figure 3-4-18
RELATIVE ABUNDANCE OF ARTHROPODS REPRESENTING FOUR MAJOR TROPHIC LEVELS COLLECTED FROM PITFALLS LOCATED ON GRIDS 1 AND 2.

of individuals in this feeding category. Predators were the dominant group on Grid 1. Spiders, Jerusalem crickets, and ground beetles were dominant species in this feeding category. Scavengers were the second most abundant group on both Grids 1 and 2. Darkling beetles comprised the majority of individuals included in this feeding category. Ground dwelling herbivores were not numerous on either grid, although, as noted above, they were relatively more abundant on Grid 1.

3.4.6.5.2 Shrub Dwelling Arthropods

3.4.6.5.2.1 Species Composition and Species Diversity

The species composition of arthropods collected from shrubs varied substantially between the three main browse species sampled. The four most abundant arthropod groups collected from each browse species in order of decreasing abundance were: serviceberry -- aphids, plant bugs, leafhoppers, tent caterpillar larvae; mountain mahogany -- psyllids, plant bugs, lynx spiders, tent caterpillar larvae; big sagebrush -- plant bugs, leafhoppers, tent caterpillar larvae, thrips (Appendix IV-B, Tables B-4-27, B-4-28, and B-4-29).

The western tent caterpillar can severely defoliate individual plants but infestations seldom persist long enough to cause lasting damage (Furniss and Krebill 1972). Leaf hoppers occur on almost all types of plants and feed principally on the leaves of the food plant. Aphids are frequently found in large numbers feeding on the sap from the stems of leaves of plants. Psyllids are similar to aphids, but have strong jumping legs, feed on plant juices, and, as in the case of most other Homoptera, the food-plant relationships are specific. Plant bugs (Hemiptera) are generally found on a variety of vegetation, feed on plant juices, and are rarely predaceous. Thrips are plant feeders and attack flowers, leaves, fruit, twigs, and buds with sucking mouth parts.

The diversity of arthropods collected from shrubs also varied between major browse species. Diversity indices were compared for all months sampled during the period August 1974-August 1976. Mountain mahogany hosted the lowest diversity of arthropods; serviceberry had a slightly higher diversity; and arthropod diversity on big sagebrush was similar to the diversity of arthropods collected from serviceberry (Figure 3-4-19; Appendix IV-B, Tables B-4-25 and B-4-26). These findings are consistent with published accounts of arthropod infestation of shrubs on western big game ranges (Furniss and Krebill 1972) which state that mountain mahogany appears to be relatively free of attack by insects and that serviceberry, although not infested by large numbers of arthropods, hosts numerous defoliators and stem insects.

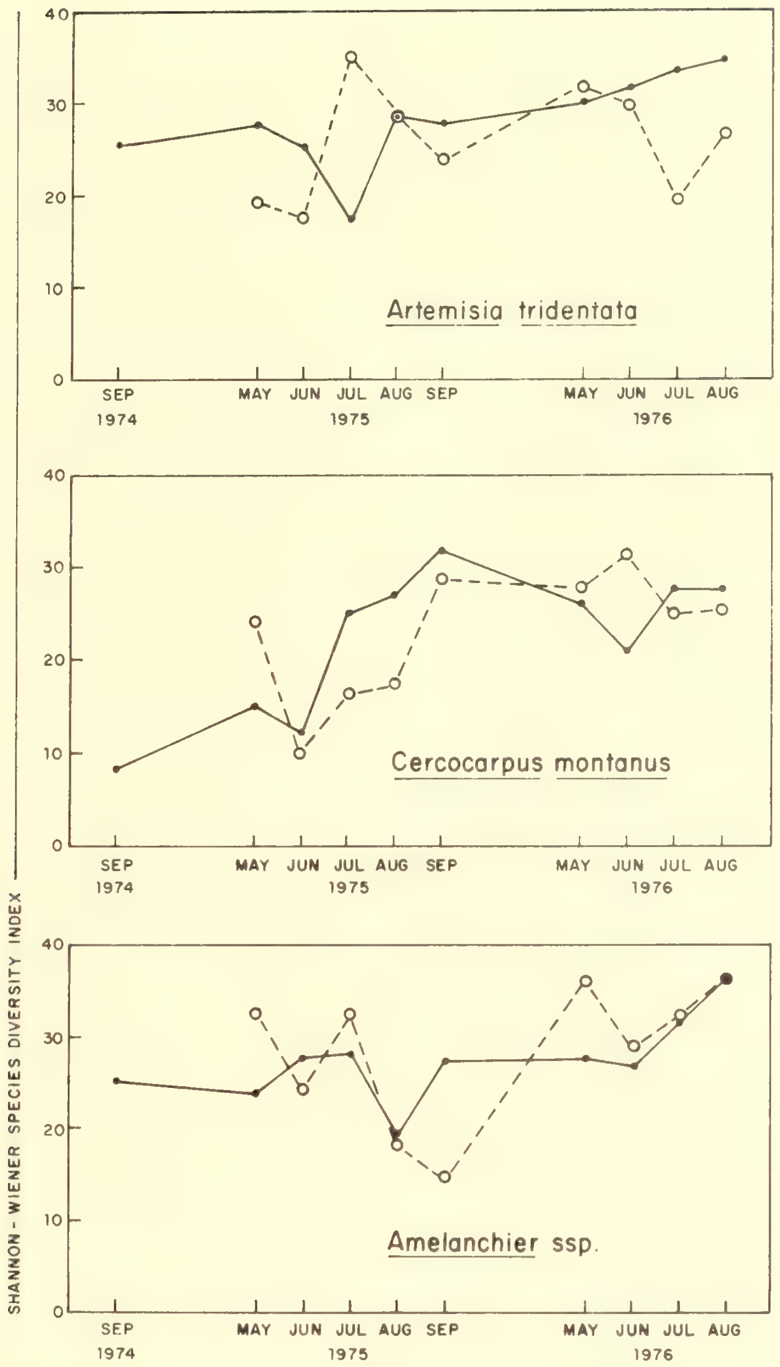


Figure 3-4-19
SPECIES DIVERSITY OF ARTHROPODS COLLECTED FROM THREE MAJOR SHRUB SPECIES ON GRIDS 1 AND 2.

3.4.6.5.2.2 Relative Abundance and Trophic Structure Analysis

During most months the percentage of shrub dwelling herbivores was approximately 80-90 percent and the percentage of predators was 10-15 percent. Other feeding groups were poorly represented except for the Formicidae (ants) which are omnivores. Herbivores (phytophagus arthropods) were not classified by subtype but several were present including: defoliating arthropods (the western tent caterpillar), sap-feeding arthropods (aphids), gall-forming types (wasps), seed eaters and non-feeders, i.e., nectarvores, pollinators, and fungivores.

Previous studies (Osborne 1974) have indicated that herbivore response to shrub phenology was the primary force influencing shrub dwelling arthropod numbers during the vegetative growing season. This response was illustrated by four herbivore species which attained their highest density estimates during the "greening up" and early growth period of plant phenophases (Osborne 1974). The same general pattern was apparent for arthropods associated with the three shrubs sampled during current studies. The total number of arthropods present on mountain mahogany and serviceberry peaked in the period July-August 1975 (Figures 3-4-20 and 3-4-21) and was apparently related to maximum growth and succulent leaves present on the shrubs during this period. The majority of arthropods captured during these periods of peak vegetative production were herbivores (80-90 percent, Figures 3-4-22 and 3-4-23).

Peak numbers of arthropods collected from big sagebrush on Grid 1 and from serviceberry on Grid 2 did not occur until September of 1975 (Figures 3-4-20 and 3-4-21). The abundance of arthropods on big sagebrush during this period may be related to the late season blooms and seed dispersal phases which have been previously documented (Osborne 1974). During late summer-early fall other shrub species have less succulent leaves and are approaching dormancy. This may account for decreased numbers of herbivores on these species and the large number of herbivores present on big sagebrush (Figure 3-4-24). Late season productivity and delays in leaf sensecence may also be responsible for high numbers of herbivores on serviceberry (Grid 2); this has not been documented previously.

Deviations from the general pattern of increased abundance of arthropods during the early growth phases of shrub species may also be related to slightly different feeding habits of arthropod herbivores. Many arthropods, such as thrips, are attracted to shrubs during the floral stages and therefore are not abundant until late in the season when floral stages appear.

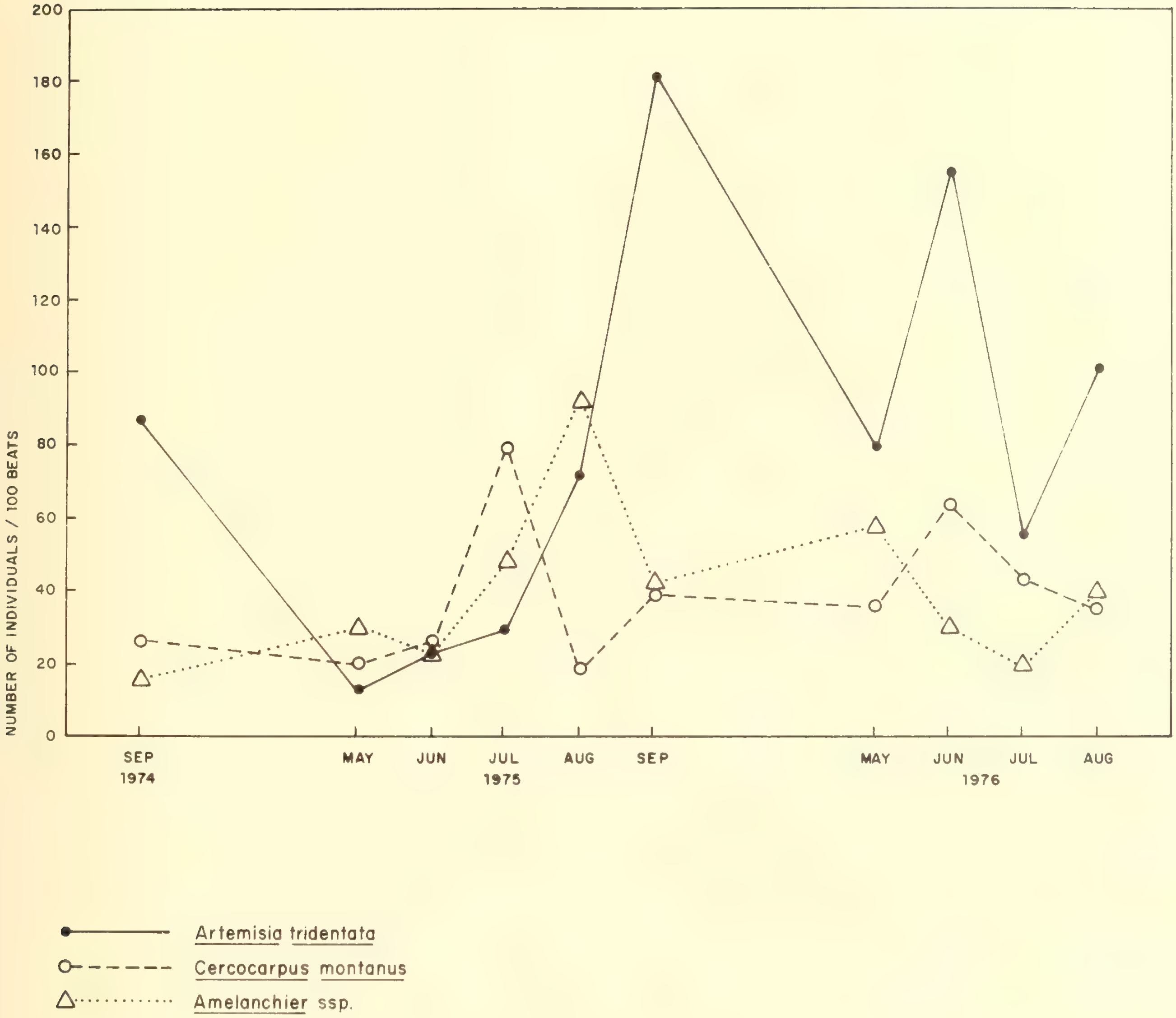


Figure 3-4-20
RELATIVE ABUNDANCE OF ARTHROPODS COLLECTED FROM THREE MAJOR SHRUB SPECIES ON GRID 1 (CHAINED PINYON-JUNIPER RANGELAND).

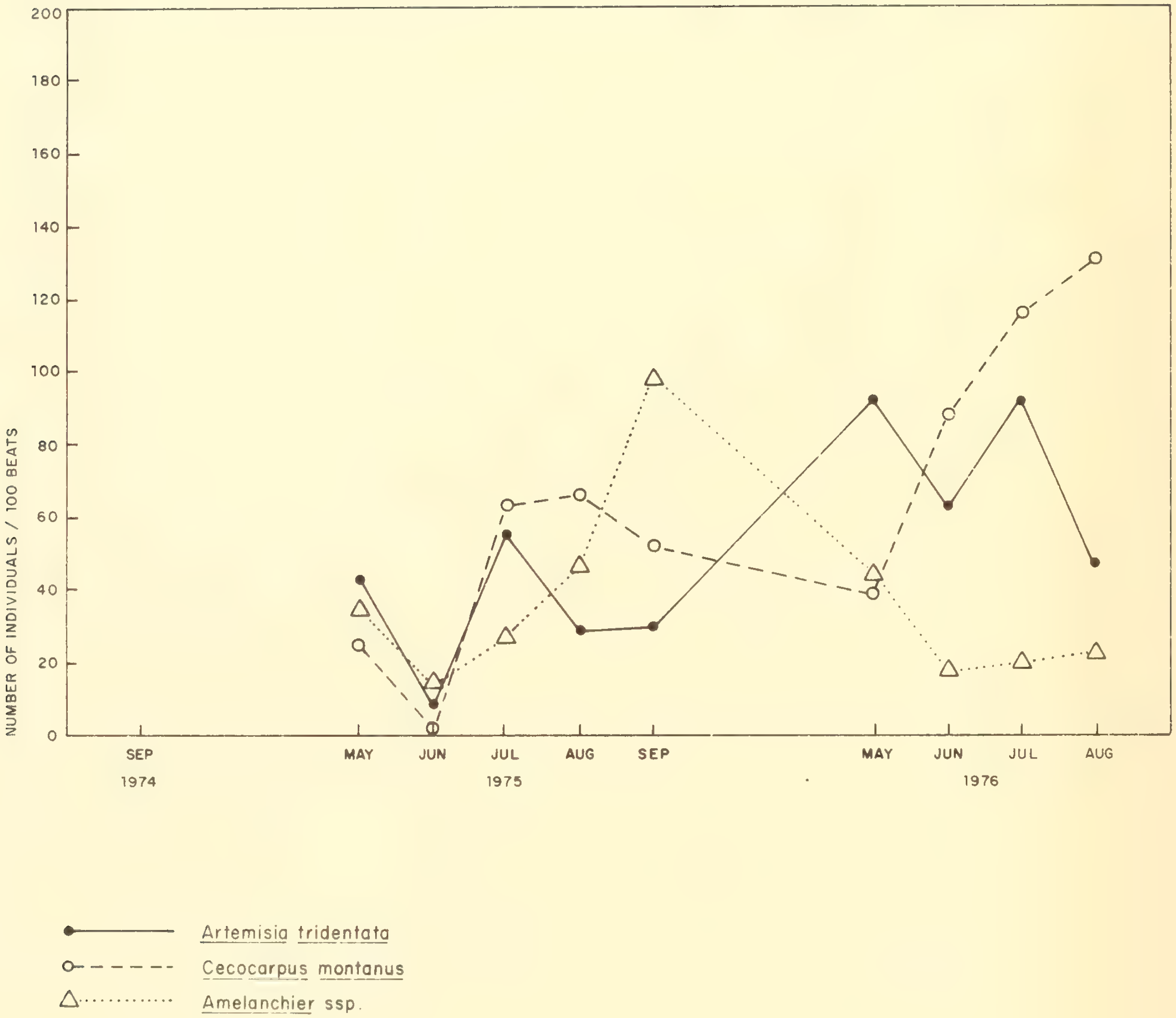


Figure 3-4-21
RELATIVE ABUNDANCE OF ARTHROPODS COLLECTED FROM THREE MAJOR SHRUB SPECIES ON GRID 2 (PINYON-JUNIPER WOODLAND).

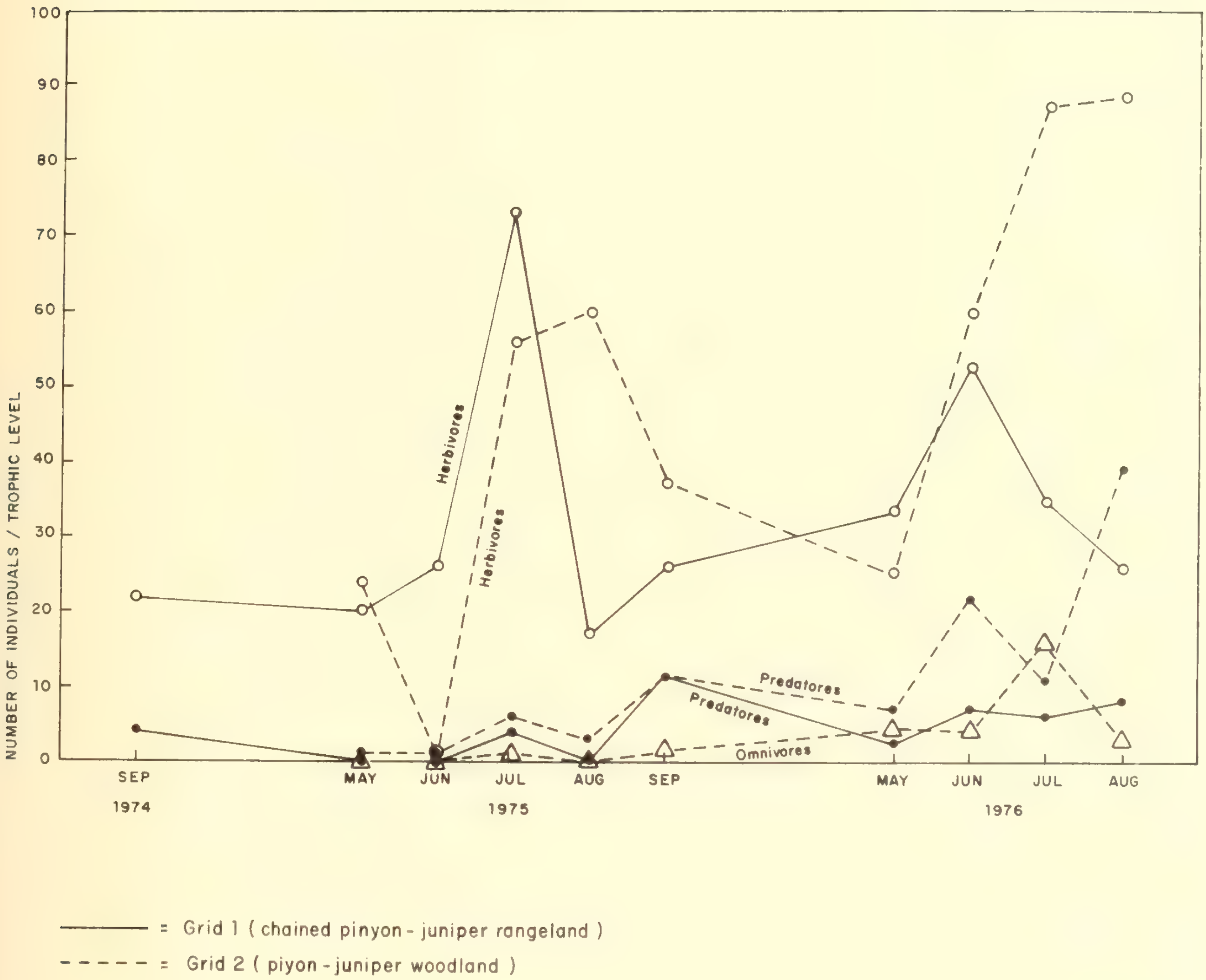


Figure 3-4-22
RELATIVE ABUNDANCE OF ARTHROPODS REPRESENTING THREE MAJOR TROPHIC LEVELS COLLECTED FROM CERCOCARPUS MONTANUS ON GRIDS 1 AND 2.

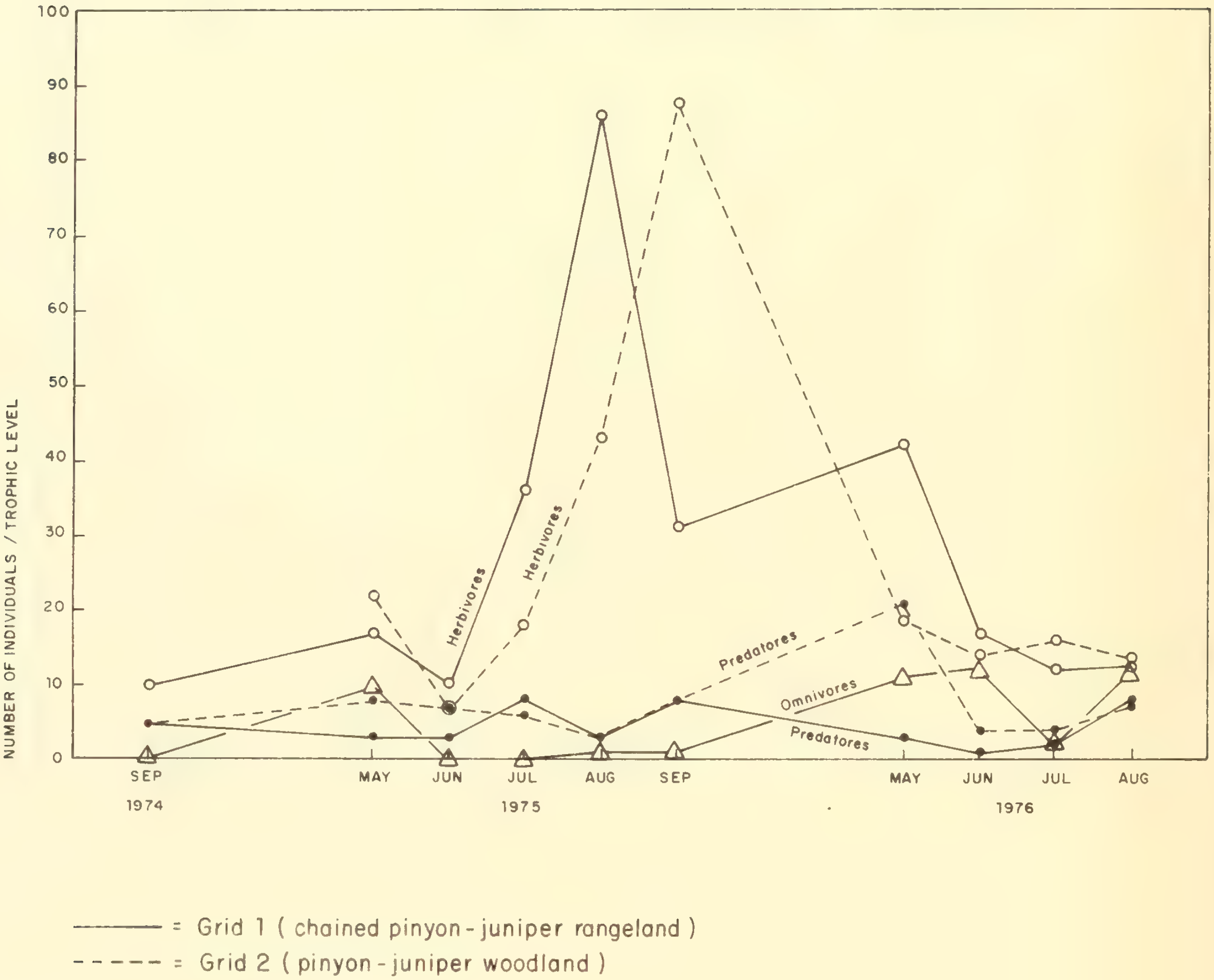


Figure 3-4-23
RELATIVE ABUNDANCE OF ARTHROPODS REPRESENTING THREE MAJOR TROPHIC LEVELS COLLECTED FROM *AMELANCHIOR* SPP. ON GRIDS 1 AND 2.

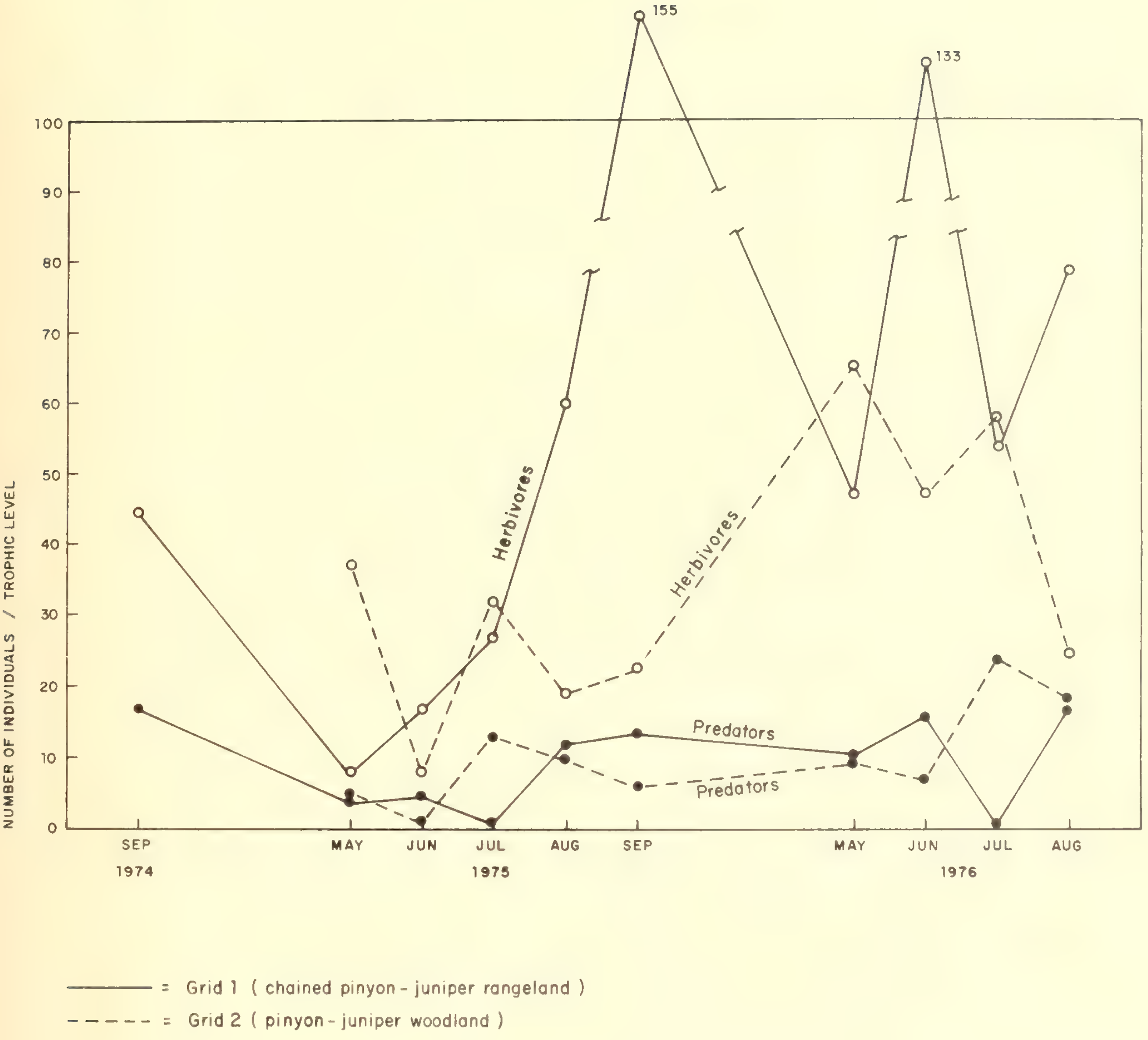


Figure 3-4-24
RELATIVE ABUNDANCE OF ARTHROPODS REPRESENTING TWO MAJOR TROPHIC LEVELS COLLECTED FROM ARTEMESIA TRIDENTATA ON GRIDS 1 AND 2.

The peak in total number of arthropods on mountain mahogany and serviceberry occurred during the period May-June in 1976 (Figures 3-4-20 and 3-4-21). The earlier peak in arthropod numbers in 1976 may be attributed to favorable temperatures and precipitation in early spring which induced early growth of these shrub species. A subsequent decline in the number of arthropods on mountain mahogany and serviceberry in Grid 1 and on serviceberry in Grid 2 during the months July-August 1976 may have been due to the hard freeze and snowfall, on approximately June 15-20, which damaged shrubs and limited productivity for the remainder of the growing season. Herbivorous arthropods comprised a majority (80-90 percent, Figures 3-4-22 and 3-4-23) of the total arthropods as they did in 1975.

The total number of arthropods on big sagebrush also showed an early peak (May-June 1976), but did not show the general downward trend following unfavorable weather in June. This gives further evidence that big sagebrush phenophases are not as affected by cold temperatures as other species and that sagebrush maintains fairly constant growth throughout an extended growing season.

The total number of arthropods collected from mountain mahogany (Grid 2) did not decline after unseasonable weather in June. Peak numbers of arthropods, the majority of which (45 percent) were psyllids, and (25 percent) lynx spiders appeared in August when arthropod abundance had already declined on most other shrub species. The reason for this abundance of psyllids is unclear; however, it may be related to weather induced physiological stress due to the June freeze and snowfall. Sleeper and Thomas (1974) report that psyllid outbreaks have been correlated with weather induced stress on plants. They postulated that physiological stress in plants increased the amount of soluble nitrogenous food and foliar accumulation available to the psyllids, thus greatly increasing the chances of young surviving and reproducing. If mountain mahogany experienced a similar physiological stress, and thus became more attractive to psyllids, the above explanation may be postulated for the findings in current studies. The increase in lynx spiders, which are generalized predators, may be a direct response to the increase in psyllids.

3.5 Aquatic Ecology

Aquatic studies were conducted during the two year baseline study in the Tract C-b vicinity. Studies included sampling of water quality and sediments, plankton, periphyton, benthos, fish, and springs and seeps. Stations were established on four streams: Stewart Creek, Willow Creek, Piceance Creek, and the White River. Baseline studies were conducted as provided for in the Lease Stipulations.

3.5.1 Rationale

Lease Stipulations require studies to determine the conditions existing prior to any development operations. These baseline data are to be used for comparison with data to be collected in the monitoring program during development operations. Studies are required on flora and fauna of the leased lands, all other lands within two miles of lease lands, and the aquatic habitat as far down stream as required by the mining supervisor.

Within these guidelines study sites were selected on Stewart Creek, Willow Creek, and Piceance Creek (which enclose the leased lands on three sides) and on the White River. In addition, springs and seeps within the study area were inventoried (Pocket Figure 3-5-1, refer to pocket, inside back cover).

As it would be impossible to study all flora and fauna on the site, representative groups of the major trophic levels were selected. Groups selected for study included: bacteria, plankton, periphyton, benthos, and fish (Pocket Figure 3-5-1).

3.5.1.1 Water Quality and Sediments

Water quality studies were conducted to provide a baseline of information on the natural fluctuations that occur in the aquatic systems in the area. This will allow detection of any degradation of water quality that might be caused by development operations. In addition, water quality parameters were of interest in relation to fluctuations within the aquatic biota. Any changes in the aquatic habitat will most likely be initiated by chemical or physical changes in water quality.

Sediment samples were collected because of their importance to benthic organisms and their possible effect upon fish spawning success. Potential erosion during development operations resulting in siltation of waterways could be analyzed relative to baseline information on seasonal changes in sediments. In addition, certain deleterious substances have the potential for accumulating to toxic levels in sediments even though not reaching significant levels within the water column.

3.5.1.2 Plankton

Plankton organisms generally include the major primary producers in lentic systems and often provide the base of the food chain. They are short lived in many cases and respond quickly to changes in their environment. For this reason they were selected for study. However, in streams plankton are often of minor importance. In lotic systems they are often the result of scouring of periphyton, rather than being truly planktonic; they are constantly being swept downstream, and by the time they respond to a change in their habitat they can be far removed from the source. They are not present in large numbers as is the case in lentic environments. For these reasons, although included in the study and collected during the baseline program, plankton samples were never analyzed from stream stations. However, light and dark bottle productivity measurements were made for lake stations.

3.5.1.3 Periphyton

Periphyton were selected for study because periphyton species are frequently the major primary producers in a lotic environment, they are indicators of water quality, and they respond to changes in water quality at a given location as they are attached to a substrate. In addition, they are a major food source for invertebrates and some fish.

3.5.1.4 Benthos

Benthic invertebrates were selected because of their importance as food for fish and invertebrate carnivores. In addition, they are the major herbivores in the aquatic system and can be indicative of changes in, or degradation of, water quality and sediment.

3.5.1.5 Fish

Fish were selected because of their importance in the food chain and public interest in their well being and survival as well as state and federal concerns and regulations governing their management. Any rare or endangered species were to be identified.

3.5.1.6 Springs and Seeps

Springs and seeps are required to be inventoried on the site. Permanent springs and seeps were studied. Those springs forming lakes were included in the aquatic sampling program for all parameters detailed above. Other permanent springs and seeps were examined for selected water quality parameters and aquatic organisms. These provided information on the aquatic life that could be supported by ground water sources.

3.5.2 Objectives

Objectives of the aquatic baseline studies were to meet the requirements of the environmental stipulations in the lease; to gather adequate data related to aquatic species to formulate the required Fish and Wildlife Management Plan, and any mitigation measures which might be required; to determine existing correlations between water quality and aquatic species to enable future detection of changes in the aquatic ecosystem attributable to oil shale development; and to determine if any rare or endangered species of fish exist in the streams or ponds of the lease area.

3.5.2.1 Water Quality and Sediments

Water quality parameters and sediments were measured for correlation with aquatic species distribution and detection of degraded water quality.

3.5.2.2 Plankton

Objectives of plankton studies were to determine relative abundance, chlorophyll content, species diversity, and primary production for plankton organisms. Only the last of these was realized.

3.5.2.3 Periphyton

Periphyton studies were conducted to determine relative abundance, species composition, and productivity for periphyton.

3.5.2.4 Benthos

Benthic macroinvertebrates were studied to determine numbers per unit area, biomass per area, seasonal abundance and diversity, composition of major taxa, and distribution.

3.5.2.5 Fish

Studies conducted on fish were designed to determine species abundance, data on age and size ratios, migration of fish, spawning, distribution, and evaluation of aquatic habitat relative to fish populations.

3.5.2.6 Springs and Seeps

The objective of studies on springs and seeps was to identify all springs and seeps in the study area, and provide data on aquatic organisms associated with springs and seeps.

3.5.3 Experimental Design

Twenty sampling stations were established during the course of the study (Pocket Figure 3-5-1). Two of these were only sampled on occasion and only for selected parameters. Eighteen permanent sampling stations were utilized for the baseline studies. Stations were established on the main watercourses surrounding the Tract. Nine stations were established on Piceance Creek, four stations on Stewart Creek, five on Willow Creek, and two on the White River. Four of the stations (two each on Stewart and Willow Creeks) were spring-fed lakes. The location and a description of each station are given in the methodology section (Appendix IV-A). Stewart and Willow Creeks flow on two sides of the Tract and drain into Piceance Creek, which flows along a third side of the Tract. Since there is no water course along the fourth side of the Tract, these three creeks provided sampling stations to examine drainage from all watersheds on the Tract. Along Piceance Creek, stations were established upstream and downstream from the Tract as well as upstream and downstream from the confluences of Stewart and Willow Creeks with Piceance Creek. The two stations on the White River were above and below the confluence of Piceance Creek with the White River.

3.5.3.1 Water Quality and Sediments

Water quality was examined at 19 stations to detect seasonal fluctuations and changes in a downstream direction. This was designed to detect the contribution to changes in water quality of the various streams draining into Piceance Creek and ultimately Piceance Creek's influence on the White River. Sediment samples were examined to detect accumulation of heavy metals and the extent of siltation seasonally as well as attempting to determine the source of sediments being added to the stream.

3.5.3.2 Plankton

Plankton samples were collected at nineteen stations to examine primary productivity and plankton abundance relative to water quality and other parameters measured. Plankton samples were never processed during the study. Primary production was estimated at the four lake stations using the dark and light bottle technique.

3.5.3.3 Periphyton

Periphyton were sampled from artificial substrates at 19 stations. At one station, horizontal and vertical substrates were used to determine the best position for periphyton growth. Vertical substrates were used at all other stations. Productivity estimates were made to compare periphyton production at the various stations. Three replicates were taken at each station for productivity and three for species indentification.

3.5.3.4 Benthos

Benthic invertebrates were collected at 19 stations from a standard unit area of substrate. Three replicates were taken at each station for analysis.

3.5.3.5 Fish

Fish were sampled at all stations. Replicate sampling was conducted at some stations during some periods. Some fish were marked and released to study migration.

3.5.3.6 Springs and Seeps

Springs and seeps were inventoried. Four were incorporated into the regular aquatic sampling program. Others were examined seasonally.

3.5.4 Brief Methodological Description

Detailed methodology is presented in Appendix IV-A. Listed below are brief accounts of the methods for the various studies conducted. A monthly sampling program was begun in August 1974. Sampling was changed to a bimonthly program in January 1975 which continued through July 1976.

3.5.4.1 Water Quality and Sediments

Water quality samples were collected at each station for analysis of 21 parameters including cations, anions, organics, inorganics, and microbiology. Analyses were conducted in the laboratory except for four parameters measured in the field. Sediment samples were collected at selected intervals from certain stations for grain size analysis and detection of heavy metals.

3.5.4.2 Plankton

Plankton samples were collected at each station and preserved for analysis. Samples were never analyzed from stream stations. Primary productivity was estimated at the lake stations using the dark and light bottle technique.

3.5.4.3 Periphyton

Periphyton samples were collected on artificial substrates from each station. Samples were taken for species indentification and for productivity estimates.

3.5.4.4 Benthos

Benthic invertebrates were collected at each station with a Surber sampler. Samples were preserved for identification and biomass estimates.

3.5.4.5 Fish

Fish were sampled at each station with electroshocker and/or seine. Some fish were sampled by hook and line. Fish were identified, measured, weighed, and released. Selected fish were preserved for further analysis. Two species of fish were marked on a regular basis to study migration, growth,and obtain a population estimate.

3.5.4.6 Springs and Seeps

Springs and seeps were inventoried. Selected springs and seeps were examined seasonally to study organisms present and measure selected water quality parameters.

3.5.5 Results and Discussion

3.5.5.1 Water Quality and Sediments

Water quality parameters were compiled for 16 stations during the study (Appendix IV-B, Tables B-5-1a-d). Data on the other two stations (S-1, P-6) were compiled from the U.S.G.S. data for the gauging stations at these locations (Appendix IV-B, Tables B-5-1a, b). Generally speaking, the surface waters of drainages in the Tract vicinity are of marginal quality. Streams are alkaline with high levels of dissolved solids. Suspended solids reach high levels during periods of peak runoff.

Listed below are general discussions of the parameters examined during the baseline studies (adapted from McKee and Wolfe 1971), followed by the results obtained from the studies.

3.5.5.1.1 Temperature

Temperature changes in bodies or streams of water may result from natural climatic phenomena or from the introduction of industrial wastes. The elevation of stream temperatures may become a serious pollution problem. Additional heat may contribute to undesirable stream conditions such as decreased oxygen capacity, increased oxygen demand, and anaerobic zones. Stream temperatures may also be increased by irrigation practices and the return of agricultural drainage. Temperature rises of 10 to 20°C have been reported. The return of cooling waters to underground aquifers has also been known to increase ground water temperatures.

Temperatures at the stations examined never exceeded 65°F during the two year study. Values ranged from freezing levels to the high of 65°F which occurred in Piceance Creek (Table 3-5-1). These temperatures are well within acceptable limits for trout streams and temperature is not a limiting factor in the streams in the vicinity of the Tract. Temperature values were graphed for each station for the two years (Figures 3-5-2 to 3-5-5) and a line fitted visually showing the general trend.

3.5.5.1.2 pH

Inasmuch as an excessive concentration of hydrogen ions may adversely affect water for one or more beneficial uses, pH is a measure of a potential pollutant.

Not only is the hydrogen ion a potential pollutant in itself, it is also related intimately to the concentration of many other substances, particularly the weakly dissociated acids and bases. The concentration of hydrogen ions, i.e., the pH, controls the degree of dissociation of many substances; and since the undissociated compounds are frequently more toxic than the ionic forms, pH may be a highly significant factor in determining limiting or threshold concentrations.

Table 3-5-1 WATER QUALITY STANDARDS, RECOMMENDED VALUES AND RANGES IN PICEANCE BASIN STREAMS FOR WATER QUALITY PARAMETERS BEING STUDIED

Minerals	Drinking Water Standards[1] (mg/l)	Recommended for Aquatic Life[1] (mg/l)	Range of Values			
			Piceance Creek	Willow Creek and Lakes	Stewart Creek and Lakes	White River
Cations (ppm)						
Calcium	30-75	<52	20-104	28-128	38-162	40-116
Magnesium	10-125	<400	19-123	49-88	62-89	9.7-28
Sodium	10	<500	75-292	104-156	120-250	11-76
Potassium	<1000	<50-200	1.7-9.4	1.1-5.2	0.9-6.7	1.2-36
Ammonia	.05-0.1	0.3-2.0	0-0.89	0-1.5	0-0.53	0-0.45
Anions (ppm)						
Hydroxide (OH)	---	<13	0-0	0-0	0-0	0-0
Carbonate	<20	(See Footnote[2])	0-48	0-36	0-38	0-18
Bicarbonate	<150	<180	323-805	287-604	323-782	116-256
Sulfate	<250	<100	83-575	259-382	330-461	39-190
Chloride	<250	<400	1.0-30.0	10-30	6.6-35.0	4-59
Nitrate	<45	<4.2	0.09-6.3	0.62-3.8	1.2-8.9	0-1.3
Organics (ppm)						
Ortho phosphate	<450	<545	0-0.3	0-0.22	0-0.2	0-0.12
Ammonia (N)	0.05-0.1	0.3-2.0	0-0.69	0-2.4	0-0.41	0-0.35
Inorganics (ppm)						
Boron	<30	<5000	0.06-2.8	0-0.67	0-530	0-1.6
Silica	<50	(See Footnote[3])	12-61	9.6-21.0	12-20	9.6-18
Iron	<0.3	<0.7	.03-35.0	0-6.4	0-20	0.04-3.9
Manganese	<0.05	<1.0	0-0.17	0-0	0-30	0-0
Nitrate (N)	<45	<4.2	0-1.4	0.04-0.86	0.04-2.0	0-0.3
Nitrite (N)	0.1-2.0	<50	0-0.04	0-0.028	0-0.044	0-0.062
Alkalinity ($CaCO_3$)	Not Detrimental	>100	310-710	265-495	295-641	95-230
Hardness ($CaCO_3$)	<250	(See Footnote[4])	240-680	360-616	425-660	140-335
Dissolved Solids	<500	500-5000	600-1524	732-1120	876-1160	176-556
pH*	No Limits - 4-9.0	6.5-8.5	7.8-9.2	5.5-9.0	7.2-9.0	7.1-8.8
Conductivity*	<500	<2000 μ mhos	690-2800	1050-1800	1300-2000	200-1975
Dissolved oxygen	---	>3-5	6-15	5-15	4-15	4.2-15
Temperature*	<60°F	<75°F	32-65°F	30-57°F	32-61°F	30-61°F
Microbiology						
Standard Plate Count			110-3,200,000	95->710,000	200-1,100,000	840-220,000
Coliform	1/100 ml	1000-10000/100 ml	23->24,000	240->24,000	240->24,000	75->24,000
Fecal Coliform	1/100 ml	20-2000/100 ml	<3-11,000	<3-4600	<3-240	<3-2100
Fecal Streptococci			<3-2400	<3-2400	<3-460	<3-240
Pathogens	0	---	0-0	0-0	0-0	0-0

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*Units as specified

[1] McKee & Wolf (1971); EPA (1972); EPA (1975)

[2] Not directly detrimental - may affect pH

[3] Favors diatom growth above 0.5

[4] No standards. Toxic metals may be less dangerous in hard water.

For complete monthly water quality data for each sampling station, see Appendix A, Table

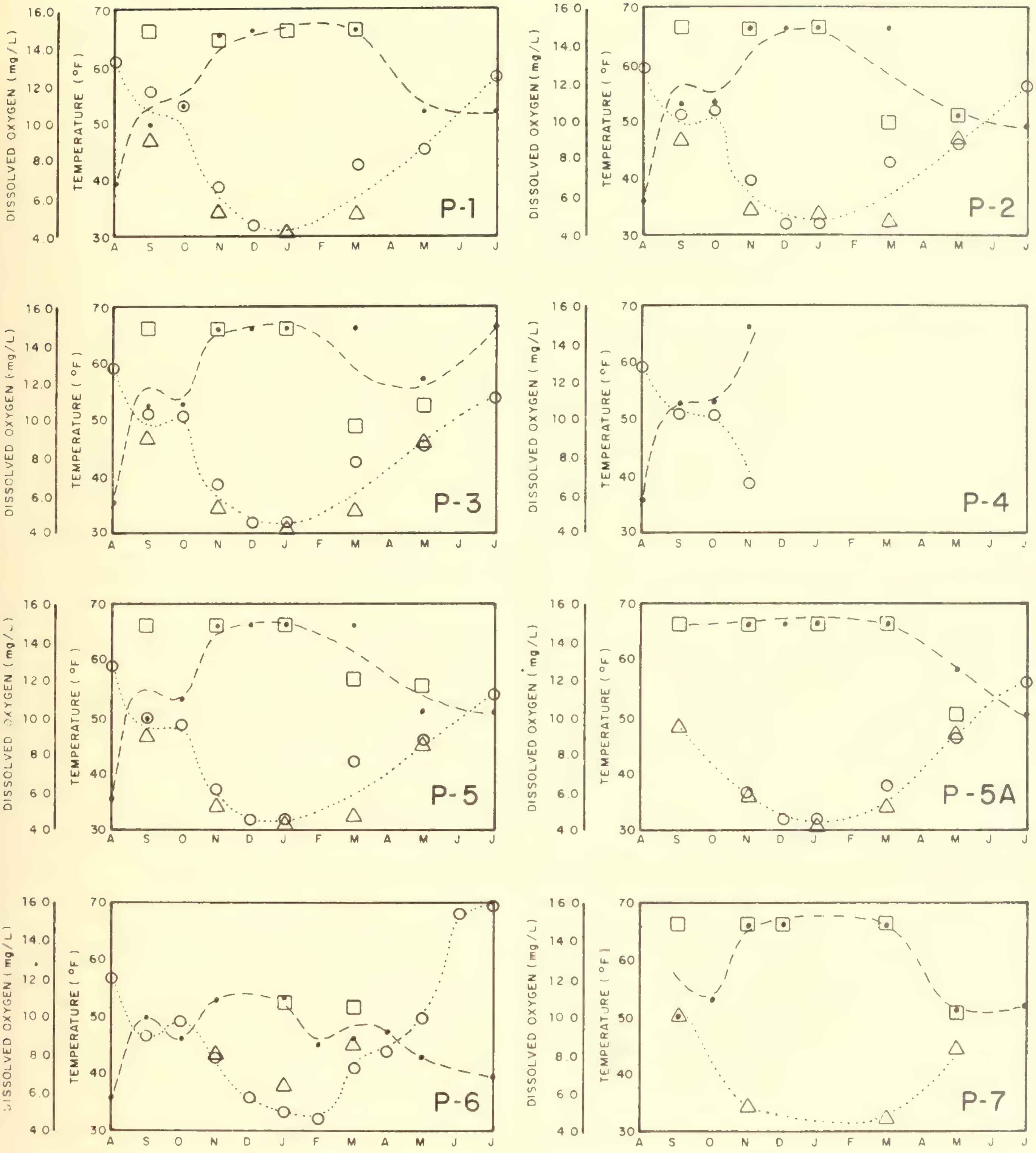

Figure 3-5-2
TEMPERATURE AND DISSOLVED OXYGEN AT THE PICEANCE CREEK STATIONS
AUGUST 1974 - JULY 1976.

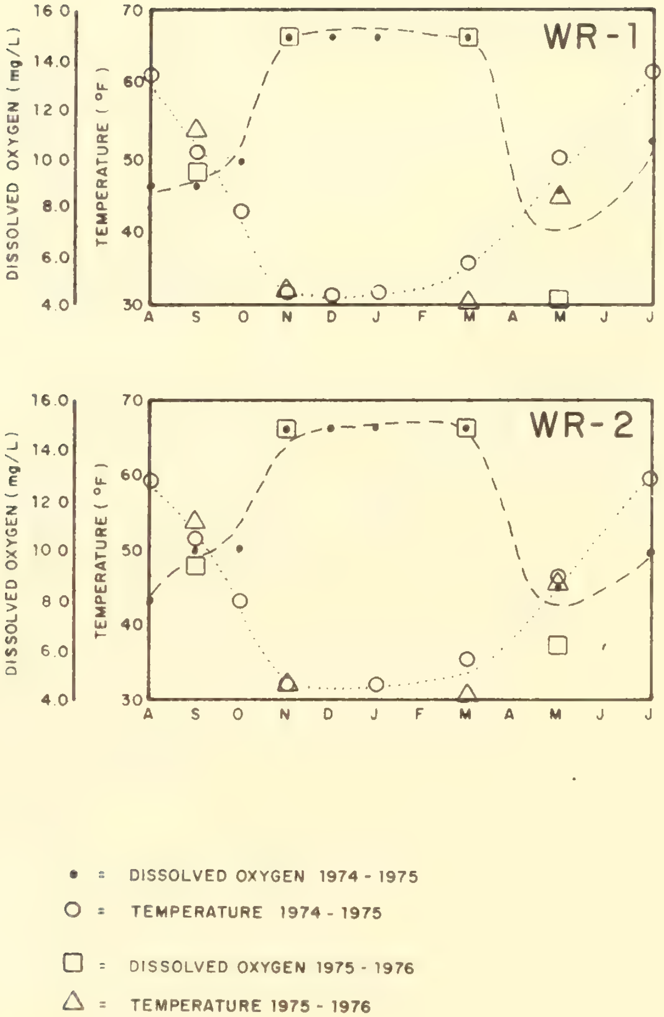

Figure 3-5-3
TEMPERATURE AND DISSOLVED OXYGEN AT THE WHITE RIVER STATIONS
AUGUST 1974 -JULY 1976.

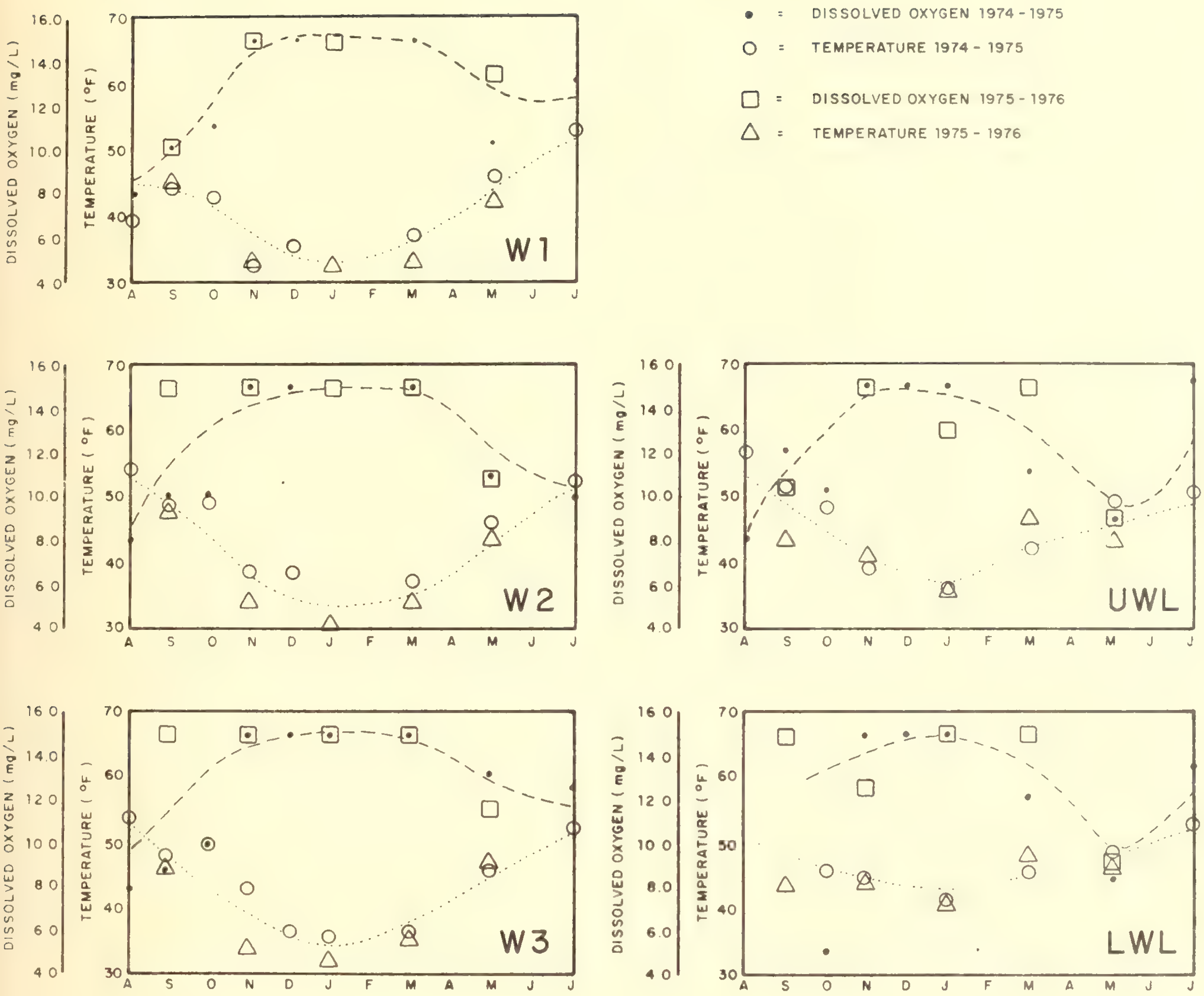

Figure 3-5-4
TEMPERATURE AND DISSOLVED OXYGEN AT THE WILLOW CREEK STATIONS.
AUGUST 1974 - JULY 1976

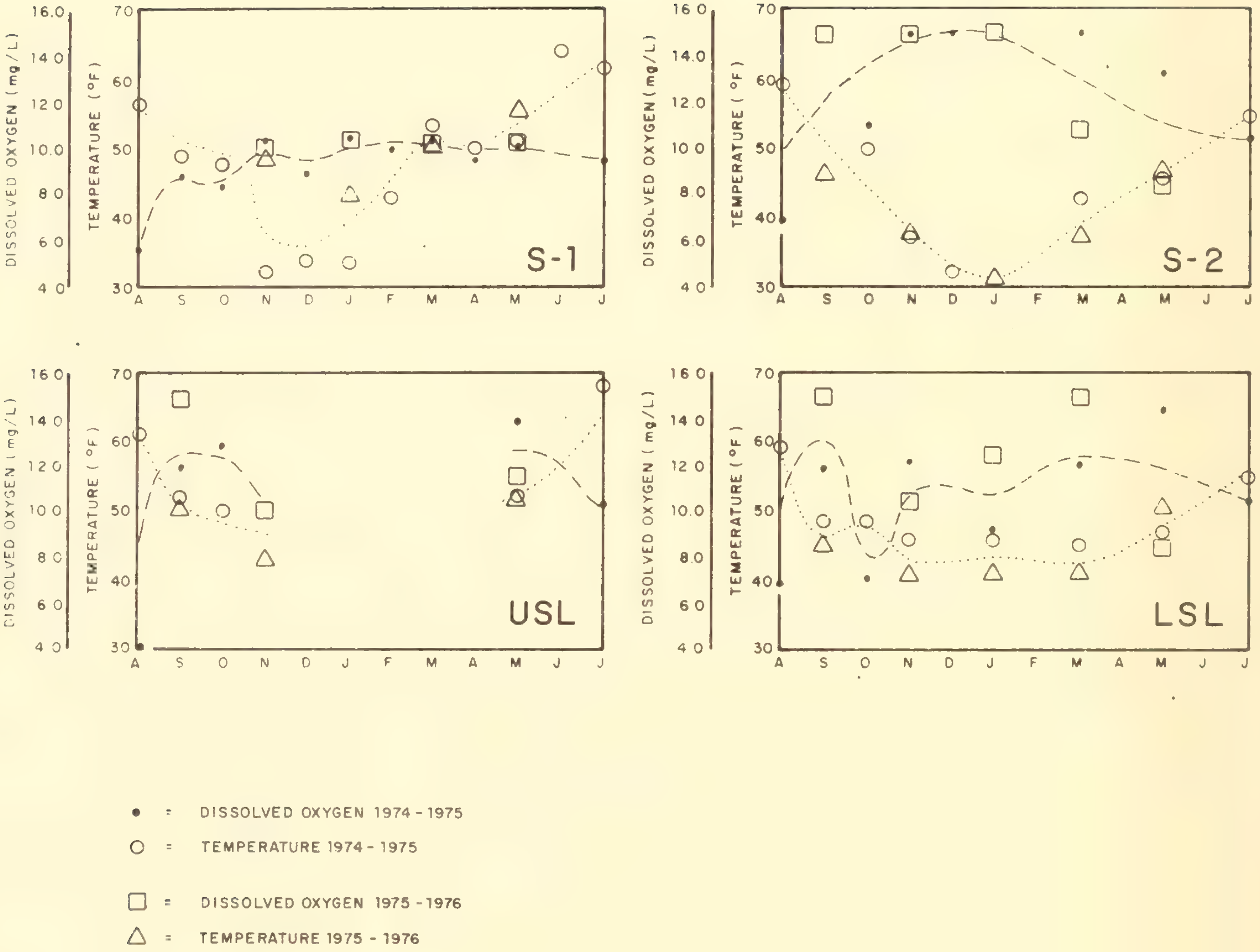

Figure 3-5-5
TEMPERATURE AND DISSOLVED OXYGEN AT THE STEWART CREEK STATIONS
AUGUST 1974 - JULY 1976.

Conversely, the concentration of weakly dissociated acids and bases markedly affects the pH value and the ease with which it can be altered. For this reason, pH should not be confused with acidity and alkalinity. The presence of carbonates, phosphates, borates, and similar ions gives water a buffering power so that the addition of an acid or base is less likely to be deleterious.

The pH values in the streams in the Tract vicinity are generally alkaline. At times, pH values exceeded the permissible limits recommended for aquatic life in all four of the streams studied (Table 3-5-1). Values ranged as high as 9.2.

3.5.5.1.3 Dissolved Oxygen

Dissolved oxygen in natural waters cannot rightfully be designated as a primary pollutant, but it does come under the category of a corollary pollutant because excessive dissolved oxygen arising from algal growths may adversely or unreasonably affect such waters for one or more beneficial uses. It is not a surplus of dissolved oxygen, however, that is the normal concern, but rather a deficiency or complete absence thereof. Inadequate dissolved oxygen in surface waters may contribute to an unfavorable environment for fish and other aquatic life, and the absence of dissolved oxygen may give rise to odoriferous products of anaerobic decomposition.

The content of dissolved oxygen in water at equilibrium with a normal atmosphere is a function of the temperature and salinity of the water. The ability of water to hold oxygen decreases with increases in temperature or dissolved solids. Natural waters are seldom at equilibrium and seldom exactly saturated with dissolved oxygen, for temperatures are changing and physical, chemical, biochemical, or biological activities are utilizing or liberating oxygen.

The oxygen requirement of fish varies with the species and age of the fish, with prior acclimatization, with temperature, with the concentration of other substances in the water, and with several other factors.

Several factors aside from the deoxygenating effects of pollutants influence the concentration of dissolved oxygen in surface waters. There is a diurnal variation owing to the photosynthetic action of algae during daylight hours and their respiration at night. Under average stream conditions, 3.0 mg/1 of dissolved oxygen, or less, should be regarded as hazardous or lethal, and to maintain a varied fish fauna in good condition the dissolved oxygen concentration should remain at 5.0 mg/1 or higher. For trout in soft water, the lower limit has been set as high as 6.0 mg/1.

Dissolved oxygen levels in the streams in the Tract vicinity are adequate for aquatic life. Levels are greater than 5.0 mg/1 in most cases (Table 3-5-1). During baseline studies there was no deficiency of dissolved oxygen in streams studied. Dissolved oxygen levels were graphed relative to the temperature values (Figures 3-5-2 to 3-5-5).

3.5.5.1.4 Specific Conductivity

Natural inland waters usually contain in solution relatively small quantities of mineral salts, but in water polluted by brines and various chemical wastes the salt concentration may rise to levels harmful to living organisms because of the increase in osmotic pressure. In studies of waters for use in irrigation and fish production, the salinity is often expressed as specific electrical conductance. The determination of conductivity is a quick method for measuring the ion concentration of water. Wide variations in the total salinity or in the concentrations of individual salts can have far reaching effects upon stream fauna, resulting even in the elimination of species.

When the osmotic pressure is sufficiently high, owing to salts in solution, water may be drawn from gills and other delicate external organs, with considerable damage to cells, or even death. High concentrations of many kinds of pollutants present this danger apart from any other toxic or corrosive effects they may have. Streams of the western plains and desert areas, particularly those carrying the more alkaline natural waters, and those draining land rich in soluble alkalis, have conductance as high as 5000 μ mhos. However, a good mixed fish fauna are usually not found in waters with a specific conductance greater than 200 μ mhos.

Streams in the Tract vicinity have relatively high specific conductance values. In Piceance Creek, values have reached 2800 μ mhos. During heavy runoff values have dropped as low as 700 in Piceance Creek and as low as 200 in the White River. In Stewart Creek and Willow Creek drainage values have not fallen below 1000 μ mhos. Fluctuations occur seasonally in all the streams studied (Appendix IV-B, Tables B-5-1a through d).

3.5.5.1.5 Cations

3.5.5.1.5.1 Calcium

Elemental calcium does not occur in nature because it oxidizes readily in air and reacts with water to release hydrogen gas. Calcium salts and calcium ions, however, are among the most commonly encountered substances in water. They may result from the leaching of soil and other natural sources or they may be contained in sewage and many types of industrial wastes. Calcium in water reduces the toxicity of many chemical compounds to fish and other aquatic fauna;

for example, mature fish have been killed by 0.1 mg/l of lead in water containing only one mg/l of calcium, but have not been harmed by this amount of lead in water containing 5 mg/l of calcium. A concentration of 50 mg/l of calcium has cancelled the toxic effect upon some fish of 2 mg/l of zinc; 0.7 mg/l of lead; and 10 mg/l of lead.

Calcium levels in Piceance Basin streams range as high as 162 mg/l. In all streams examined, calcium levels exceeded the recommendations for aquatic life (<52 mg/l) at some time during the year (Table 3-5-1).

3.5.5.1.5.2 Magnesium

With the exception of the hydroxide at high pH values, magnesium salts are very soluble; even the carbonate will dissolve to the extent of 100 to 300 mg/l at normal temperatures. The relative concentrations of magnesium and calcium in water may be one factor controlling the distribution of certain crustacean fishfood organisms, such as copepods, in streams. Among U.S. waters supporting a good fish fauna, ordinarily 5 percent have less than 3.5 mg/l of magnesium; 50 percent have less than 7 mg/l; and 95 percent have less than 14 mg/l.

Magnesium levels in the streams studied around the Tract ranged as high as 123 mg/l. The lowest value in Piceance Creek was 19 mg/l. In Stewart and Willow Creeks the lowest values were around 50 to 60 mg/l. The White River had considerably lower levels of magnesium (9.7-28) than the streams in the Tract vicinity (Appendix IV-B, Tables B-5-1a-d). However, magnesium levels in all streams were within recommended levels for aquatic life (Table 3-5-1).

3.5.5.1.5.3 Sodium

Owing to the fact that most sodium salts are extremely soluble in water, any sodium that is leached from soil or discharged to streams by industrial wastes will remain in solution. Some sodium may be removed by ion-exchange phenomena in the passage of ground waters through certain soils.

Of the U.S. waters supporting a good fish fauna, ordinarily the concentration of sodium plus potassium is less than 6 mg/l in about 5 percent; less than 10 mg/l in about 50 percent; and less than 85 mg/l in about 95 percent. Toxicity of sodium salts depends largely on the anion involved, the chromate being exceedingly toxic, and the sulfate least so.

Sodium levels were highest in Piceance Creek (292 mg/l) and lowest in the White River (Appendix IV-B, Tables B-5-1a-d). Values in all streams were within limits recommended for aquatic life (<400 mg/l).

3.5.5.1.5.4 Potassium

Potassium is one of the most active metals and reacts vigorously with oxygen and water. For that reason it is not found free in nature but only in the ionized or molecular form. Potassium resembles sodium in many of its properties, and potassium salts can be substituted for sodium salts in many industrial applications. Owing to the fact that the common salts of potassium, even the carbonate and hydroxide, are extremely soluble, they are not readily separated from water by natural processes other than evaporation. The toxicity of potassium to fish is reduced by calcium, and, to a lesser degree, by sodium. Potassium is more toxic to fish and shellfish than calcium, magnesium or sodium. It has been observed that potassium stimulates plankton growth.

Potassium levels in all streams studied were well within the recommended levels for aquatic life (Table 3-5-1). Values were generally 0.9 to 9.4 mg/l except in the White River, where values ranged as high as 36 mg/l.

3.5.5.1.5.5 Ammonia

In surface ground water ammonia generally results from the decomposition of nitrogenous organic matter, being one of the constituents of the complex nitrogen cycle. However, it may also result from the discharge of industrial wastes.

The toxicity of ammonia and ammonium salts to aquatic animals is directly related to the amount of undissociated ammonium hydroxide in the solution, which in turn is a function of pH as explained above. Thus, a high concentration of ammonium ions in water at a low pH may not be toxic, but if the pH is raised toxicity will probably increase.

The presence of carbon dioxide, up to concentrations in the range of 15 to 60 mg/l, appears to reduce the toxicity of ammonia presumably by lowering the pH value. Inasmuch as CO_2 is excreted by the fish, the pH value at the gill surface will be lower than in the bulk of the solution, thereby reducing the proportion of unionized ammonia at the gill.

The toxicity of ammonia to fish is increased markedly at low tensions of dissolved oxygen. A concentration of non-ionized ammonia equivalent to 0.2 mg/l of nitrogen decreased the survival time of trout at a level of dissolved oxygen that would otherwise have no lethal effect. The concentration of excreted carbon dioxide at the gill surface varies with the oxygen content of the water; hence as the oxygen tension is reduced, the concentration of excreted CO_2 is also reduced and the pH value of the water in contact with the gill surface rises, leading to an increased toxicity of an ammonia solution.

Ammonia levels in the streams in the Tract vicinity were within limits recommended for aquatic life (Table 3-5-1). Highest values occurred in Willow Creek.

3.5.5.1.6 Anions

3.5.5.1.6.1 Hydroxide

The concentration of hydroxyl ions in any solution is indicated by the pH value (see pH). Hydroxides also contribute to the alkalinity of water and markedly influence carbonate equilibria (see Alkalinity, Carbonates, and Bicarbonates).

Hydroxide levels were negligible in all streams in the Tract vicinity (Appendix IV-B, Tables B-5-1a-d). See pH.

3.5.5.1.6.2 Carbonate

The concentration of carbonates in natural and polluted waters is a function not only of the substances added thereto but also of the temperature, pH, cations, and other dissolved salts. Inasmuch as many of the carbonates are quite insoluble in water, generally more so than the chlorides, nitrates, or sulfates, there is a tendency for certain carbonate salts to be removed from polluted waters by precipitation and absorption. For these reasons, carbonates are less widely present than chlorides and sulfates in western irrigation waters. In general, it may be expected that carbonates, in themselves, are not detrimental to fish life but their buffering action and effect upon pH may contribute to the toxicity of high pH value.

Carbonate levels in the streams ranged from 0 to 48 mg/l (Appendix IV-B, Tables B-5-1a-d). Highest levels occurred in Piceance Creek.

3.5.5.1.6.3 Bicarbonates

The concentration of bicarbonates in natural and polluted waters is a function not only of the bicarbonates added thereto but also of the temperature, pH, and concentration of other dissolved solids.

The concentration of bicarbonates depends on the pH value and the concentration of carbonates.

Bicarbonates may reach water from many natural sources, including absorption of CO_2 from the air and the decomposition of organic matter, or they may be discharged by innumerable industrial processes, for bicarbonates are among the most commonly used salts.

Other than the fact that excessive bicarbonates add to the salinity and total solids content of water, and through the complex operations of the carbonate equilibria tend to form carbonates and scale at high temperatures, bicarbonates in water are seldom considered to be detrimental. In U.S. waters that support a good fish fauna, 5 percent of such waters have less than 40 mg/l of bicarbonate, 50 percent have less than 90 mg/l, and 95 percent have less than 180 mg/l.

Bicarbonate levels in the streams ranged as high as 805 mg/l (Appendix IV-B, Tables B-5-1a-d). Levels exceeded those recommended for aquatic life in all streams studied. The lowest value in any of the streams surrounding the Tract was 287 mg/l (Willow Creek). In the White River the lowest value was 116 mg/l.

3.5.5.1.6.4 Sulfate

Sulfates occur naturally in water, particularly in the western United States, as a result of leachings from gypsum and other common minerals. They may also occur as the final oxidized stage of sulfides, sulfites, and thiosulfates; e.g., iron pyrite (FeS) may be leached from abandoned coal mines and the sulfide ions converted in surface streams to sulfates. Sulfates may also occur as the oxidized state of organic matter in the sulfur cycle, but they, in turn, may serve as sources of energy for sulfate-splitting bacteria.

Sulfates may be discharged in numerous industrial wastes.

The sulfates of lead, barium, strontium, and calcium are relatively insoluble, but sodium, potassium, and ammonium sulfate are highly soluble. In U.S. waters that support good game fish, 5 percent of the waters contain less than 11 mg/l of sulfates, 50 percent less than 32 mg/l, and 95 percent less than 90 mg/l. Experiments indicate that water containing less than 0.5 mg/l of sulfate will not support growth of algae.

Sulfate levels were high in all streams studied. Values ranged as high as 575 mg/l (Appendix IV-B, Tables B-5-1a-d). All streams exceeded the levels recommended for aquatic life at certain times of the year and Willow and Stewart Creeks exceeded recommended levels throughout the year.

3.5.5.1.6.5 Chloride

Chlorides are found in practically all natural waters. They may be of natural mineral origin, or derived (a) from sea water contamination of underground supplies, (b) from salts spread on fields for agricultural purposes, (c) from human or animal sewage, or (d) from industrial effluents.

Among U.S. waters supporting a good fish fauna, ordinarily the concentration of chlorides is below 3 mg/1 in 5 percent; below 9 mg/1 in 50 percent; and below 170 mg/1 in 95 percent of such waters. Chlorinity is closely related to the total salinity and its effects on osmosis; hence it is evident that fresh-water fish cannot tolerate excessive changes in salinity.

Chloride levels in the streams did not exceed 59 mg/1 (Appendix IV-B, Tables B-5-1a-d). The White River had the highest levels. Piceance, Stewart, and Willow Creeks had maximum concentrations around 30 mg/1.

3.5.5.1.6.6 Nitrate

Nitrates are the end product of the aerobic stabilization of organic nitrogen, and as such they occur in polluted waters that have undergone self-purification or aerobic treatment processes. Nitrates also occur in percolating ground waters as a result of excessive application of fertilizer or leaching from cesspools. In a few instances, nitrates may be added to a stream or ground water by natural degradation or directly by inorganic industrial wastes, but such sources are relatively insignificant.

In spite of their many sources, nitrates are seldom abundant in natural surface waters, for they serve as an essential fertilizer for all types of plants, from phytoplankton to trees. Photosynthetic action is constantly utilizing nitrates and converting them to organic nitrogen in plant cells. In deep ground waters, however, this action is not possible and, consequently, it is in such waters that excessive and deleterious concentration of nitrates are often found. High nitrate concentration of effluents and water stimulate the growth of plankton and aquatic weeds. By increasing plankton growth and the development of fish food organisms, nitrates indirectly foster increased fish production. Among U.S. waters supporting a good fish life, ordinarily 5 percent have less than 0.2 mg/1 of nitrates; 50 percent have less than 0.9 mg/1; and 95 percent have less than 4.2 mg/1.

Nitrate levels have reached 8.9 mg/1 in Stewart Creek and as high as 6.3 mg/1 in Piceance Creek (Appendix IV-B, Tables B-5-1a-d). Nitrate levels in the White River have not exceeded 1.3 mg/1.

3.5.5.1.7 Organics

3.5.5.1.7.1 Ortho-phosphates

Phosphates may occur in surface or ground waters as a result of leaching from minerals or ores in natural processes of degradation or from agricultural drainage, as one of the stabilized products of decomposition of organic matter, or as a result of industrial wastes. In surface waters, however, phosphates are seldom found in significant concentrations because they are utilized by plants and converted into cell structures by photosynthetic action. Higher concentrations are likely to occur in ground waters that receive leachings from excessive application of fertilizer, from cesspools, or from the recharge of cooling waters. The discharge of excessive amounts of phosphates to streams or lakes may result in an overabundant growth of algae with concomitant odors and detriment to fish. In themselves, however, phosphates seldom exhibit toxic effects upon fish and other aquatic life and may be beneficial to fish culture by increasing algae and zooplankton.

Organic phosphates are used extensively in pesticides, and as such exhibit selective toxicity to many forms of aquatic life.

Phosphate levels are low in the streams studies. Values ranged from 0 to 0.3 mg/l.

3.5.5.1.7.2 Ammonia (N)

Ammonia and ammonium ions have previously been discussed under ammonia (above). Whenever ammonia gas or ammonium salts are dissolved in water, or when an ammonium ion is formed in the decomposition of organic matter, the undissociated compound NH_4OH results. The proportion of ammonium ion and undissociated base is a function of pH, as explained under Ammonia and the toxicity of the resulting solution depends primarily on the concentration of NH_4OH, i.e., the undissociated compound is the toxic principle.

Inasmuch as toxicity varies considerably with pH and hence is a function of the buffering action of the water used, it is difficult to compare the results of many investigators. Toxic concentration of ammonium hydroxide toward fish have been reported for concentrations ranging from 4 to 37 mg/l.

Ammonia (N) concentrations in the streams studied varied from 0 to 2.4 mg/l. Highest levels were found in Willow Creek, followed by Piceance Creek (Appendix IV-B, Tables B-5-1a-d).

3.5.5.1.8 Inorganics

3.5.5.1.8.1 Boron

Never found in nature in its elemental form, boron occurs as sodium borate (borax) or as calcium borate (colemanite) in mineral deposits and in some natural waters.

Boron may be substituted for carbon in many organic compounds.

Boric acid can be toxic to fresh water fish without lowering the pH to 5.0. Thus, pH is not a reliable index of dangerous pollution by boric acid.

Boron was present in low levels in the streams studied except for Stewart Creek, where the boron level reached 530 mg/1 (Appendix IV-B, Tables B-5-1a-d). All values were within the recommendation for aquatic life.

3.5.5.1.8.2 Silica

The element silicon is not found free in nature but it occurs as silica in sand or quartz and as silicates in minerals. Silicon dioxide, or silica, is insoluble in water or acids, except hydroflouric, but it may occur in natural waters as finely divided or colloidal suspended matter, in concentrations of one to 40 mg/1.

In concentrations found in natural or treated waters, silica or silicates appear to have caused no adverse physiological effects. An abundance of silica in water, along with other necessary nutrients, favors the growth of diatoms. Blooms of diatoms synthesize silica into the tests of the organisms and thereby lower the content in the water. The diatom, Asterionella, and possibly other algae, require silica in concentrations above 0.5 mg/1 for growth in ponds, and cannot utilize silica when present at lower concentrations.

Silica levels in the streams studied varied from 9.6 to 61 mg/1 (Appendix IV-B, Tables B-5-1a-d). Highest levels were found in Piceance Creek. Silica levels in Willow and Stewart Creeks did not exceed 21 mg/1.

3.5.5.1.8.3 Iron

Metallic iron and its common alloys are corroded by water in the presence of oxygen. The resulting products of corrision, in which the iron is in the ionic or molecular state, may in themselves be pollutants of water. In addition to corrosion products, natural waters may be polluted by iron-bearing industrial wastes and by the leaching of soluble iron salts from soil and rocks, e.g., acid mine drainage and iron-bearing ground water.

Although many of the ferric and ferrous salts such as the chlorides are highly soluble in water, ferrous ions are readily oxidized in natural surface waters to the ferric condition and form insoluble hydroxides. These precipitates tend to agglomerate, flocculate, and settle or be absorbed on surfaces; hence the concentration of iron in well-aerated waters is seldom high. In ground water, the pH and Eh may be such that high concentrations of iron remain in solution. When iron is added to water in the form of chlorides, sulfates, or nitrates, the salt dissociates but the resulting ferrous or ferric ions combine with hydroxyl ions to form precipitates. Hence, very little of the iron remains in solution; but if the dosage is sufficient and the water is not strongly buffered, the addition of a soluble iron salt may lower the pH of the water to a toxic level. Furthermore, the deposition of iron hydroxides on the gills of fish may cause an irritation and blocking of the respiratory channels. Heavy precipitates of ferric hydroxide may smother fish eggs.

Among U.S. waters supporting a good fish life, ordinarily 5 percent have 0.0 mg/1 of iron; 50 percent have less than 0.3 percent mg/1; and 95 percent have less than 0.7 mg/1.

Iron levels in the streams studied reached high levels at times. Values exceeded the recommended levels for aquatic life in all streams studied. The highest value (35 mg/1) was found in Piceance Creek. This greatly exceeds the recommended level for iron.

3.5.5.1.8.4 Manganese

Manganese metal is not found pure in nature, but its ores are very common and widely distributed. The chlorides, nitrates, and sulfates are highly soluble in water; but the oxides, carbonates and hydroxides are only sparingly soluble. For this reason, manganic or manganous ions are seldom present in natural surface waters in concentrations above 1.0 mg/1. In ground water subject to reducing conditions, manganese can be leached from the soil and occur in high concentrations. Manganese frequently accompanies iron in such ground waters.

The toxicity of manganese toward fish is dependent upon many factors. Toxic action is slow and manganese does not appear to precipitate the gill secretions. The toxicities of manganous chloride and manganous sulfate are slight, being about 2400 and 1240 mg/1 of manganese, respectively. Manganese appears to be somewhat antagonistic to the toxic action of nickel toward fish.

The permanganates are much more toxic to fish than the manganous salts. Permanganates killed fish in 8 to 18 hours at concentrations of 2.2 to 4.1 of manganese. However, permanganites are not stable for long in water.

Manganese levels were very low in most streams studied (0 - 0.17 mg/1) except for Stewart Creek, where values reached 30 mg/1 (Appendix IV-B, Tables B-5-1a-d). This exceeds the level recommended for aquatic life.

3.5.5.1.8.5 Nitrate (N)

Discussed above.

Nitrate (N) levels were within acceptable limits at all stations studied (Table 3-5-1).

3.5.5.1.8.6 Nitrite (N)

In water, nitrites are generally formed by the action of bacteria upon ammonia and organic nitrogen. Owing to the fact that they are quickly oxidized to nitrates, they are seldom present in surface waters in significant concentrations. In conjunction with ammonia and nitrate, nitrites in water are often indicative of pollution. However, the presence of nitrite does not always signify pollution. Nitrite and nitrate stimulate the growth of plankton in reservoirs. Tests with minnows showed that a concentration of 50 mg/1 of sodium nitrite could be fatal in 14 days, while 10,000 mg/1 destroyed the minnows in 1.5 hours.

Nitrite (N) levels were very low in all streams studied, as would be expected (discussion above). Values were well within acceptable limits recommended for aquatic life. (Table 3-5-1).

3.5.5.1.8.7 Alkalinity ($CaCO_3$)

Like acidity, alkalinity is not a specific polluting substance, but rather a combined effect of several substances and conditions. It is a measure of the power of a solution to neutralize hydrogen ions and it is expressed in terms of an equivalent amount of calcium carbonate. Alkalinity is caused by the presence of carbonates, bicarbonates, hydroxides and to a lesser extent by borates, silicates, phosphates, and organic substances. Like acidity, alkalinity is related to pH but high alkalinities should not be confused with high pH values. Thus, a relatively pure water with a pH value of 7.0 will have a low total alkalinity whereas a buffered water at pH 6.0 will have a high total alkalinity.

Some natural waters, especially those in the southwestern U.S., are highly alkaline while others, such as those in western Washington or the New England states, are low in alkalinity. The alkalinities of streams are frequently increased by the addition of municipal sewage and many industrial wastes.

None of the strong alkalies, such as calcium, potassium, and sodium hydroxide, has been shown clearly to be lethal to fully developed fish in natural waters when its concentration is insufficient to raise the pH well above 9.0. Interference with normal development and other damage to fish life sometimes may occur, however, at lower pH values. When caused almost entirely by bicarbonates, alkalinity does not seem to have any harmful effect upon plankton and other aquatic life.

It is generally recognized that the best waters for the support of diversified aquatic life are those with pH values between 7 and 8, having a total alkalinity of 100 to 120 mg/1 or more. This alkalinity serves as a buffer to help prevent any sudden change in pH value, which might cause death to fish or other aquatic life.

Alkalinity values in all streams studied exceeded 100 mg/1 (Appendix IV-B, Tables B-5-1a-d). The highest value was found in Piceance Creek (710 mg/1). The lowest value was found in the White River. Piceance, Stewart, and Willow Creeks had alkalinity values near 300 or greater during the study.

3.5.5.1.8.8 Hardness ($CaCO_3$)

The term "hardness" is applied to the soap-neutralizing power of a water. Hardness is attributable principally to calcium and magnesium ions.

The hardness is expressed in terms of an equivalent concentration of calcium carbonate.

Hardness in water may be caused by the natural accumulation of salts from contact with soil and geological formations, or it may enter from direct pollution by industrial wastes. Some industrial wastes have an indirect effect upon hardness in ground water by increasing the carbonic-acid content and favoring the solution of calcium and magnesium salts. Return flow from irrigation drainage also increases hardness.

The growth of fish in aquaria may be limited by the hardness of the water. The concentration of calcium in vertebrae of fish is not affected by the hardness of the water.

Soft water solutions increase the sensitivity of fish to toxic metals; in hard waters toxic metals may be less dangerous.

Hardness values ranged from 140 to 680 mg/1 (Appendix IV-B, Tables B-5-1a-d). The highest values were found in Piceance, Stewart, and Willow Creeks.

3.5.5.1.9 Dissolved Solids

In natural waters the dissolved solids consist mainly of carbonates, bicarbonates, chlorides, sulfates, phosphates, and possible nitrates of calcium, magnesium, sodium, and potassium, with traces of iron, manganese and other substances. The mineral content of natural waters may be lowered artificially by dilution, or raised by the addition of chemical wastes, dissolved salts, acids, alkalis, gas and oil-well brines, or drainage waters from irrigated land.

All salts in solution change the physical and chemical nature of the water and exert osmotic pressure. Some have physiological or toxic effects as well. Possible synergistic or antagonistic interactions between mixed salts in solution may cause the effects of these salts to be different from those of salts separately, and the presence of poisonous salts (such as nitrates, sulfides, and flourides) can render waters dangerous for use whose total solids concentration is apparently within acceptable limits.

Among inland waters in the United States supporting a good mixed fish fauna, about 5 percent have dissolved solids concentration under 72 mg/l; about 50 percent under 169 mg/l; and about 95 percent under 400 mg/l. Some fish are adapted to living in more saline waters.

Fish can become acclimatized slowly to higher salinities than those to which they are accustomed, but fish in waters of low salinity cannot survive sudden exposure to high salinities, such as those resulting from discharges of oil-well brines.

Dissolved solids may influence the toxicity of heavy metals and organic compounds to fish and other aquatic life, primarily because of the antagonistic effect of hardness on heavy metals. Chromates, copper, cyanides, detergents, phenolic compounds, zinc, and several other substances are generally more toxic in distilled water than in hard water of high dissolved solids.

Dissolved solid levels in the streams reach high levels during low flow periods. The White River had the lowest levels of dissolved solids, while Piceance Creek had the highest levels (Appendix IV-B, Table B-5-1a-d). All values were within acceptable limits for aquatic life. Dissolved solid values were plotted for each station for the two year study (Figures 3-5-6 to 3-5-9).

3.5.5.1.10 Microbiology

3.5.5.1.10.1 Coliform Bacteria

The direct search for the presence of a specific pathogen in water is too uneconomical, slow, and unwieldy for routine control purposes. Instead, water is examined for an indication of fecal contamination, and when such indication is found, it is assumed that the water is potentially dangerous.

The coliform group of organisms includes, by definition, "all aerobic and facultative anaerobic, gram-negative, nonspore forming, rod-shaped bacteria that ferment lactose with gas formation within 48 hours at 35^0C." It embraces organisms of diverse origin among which

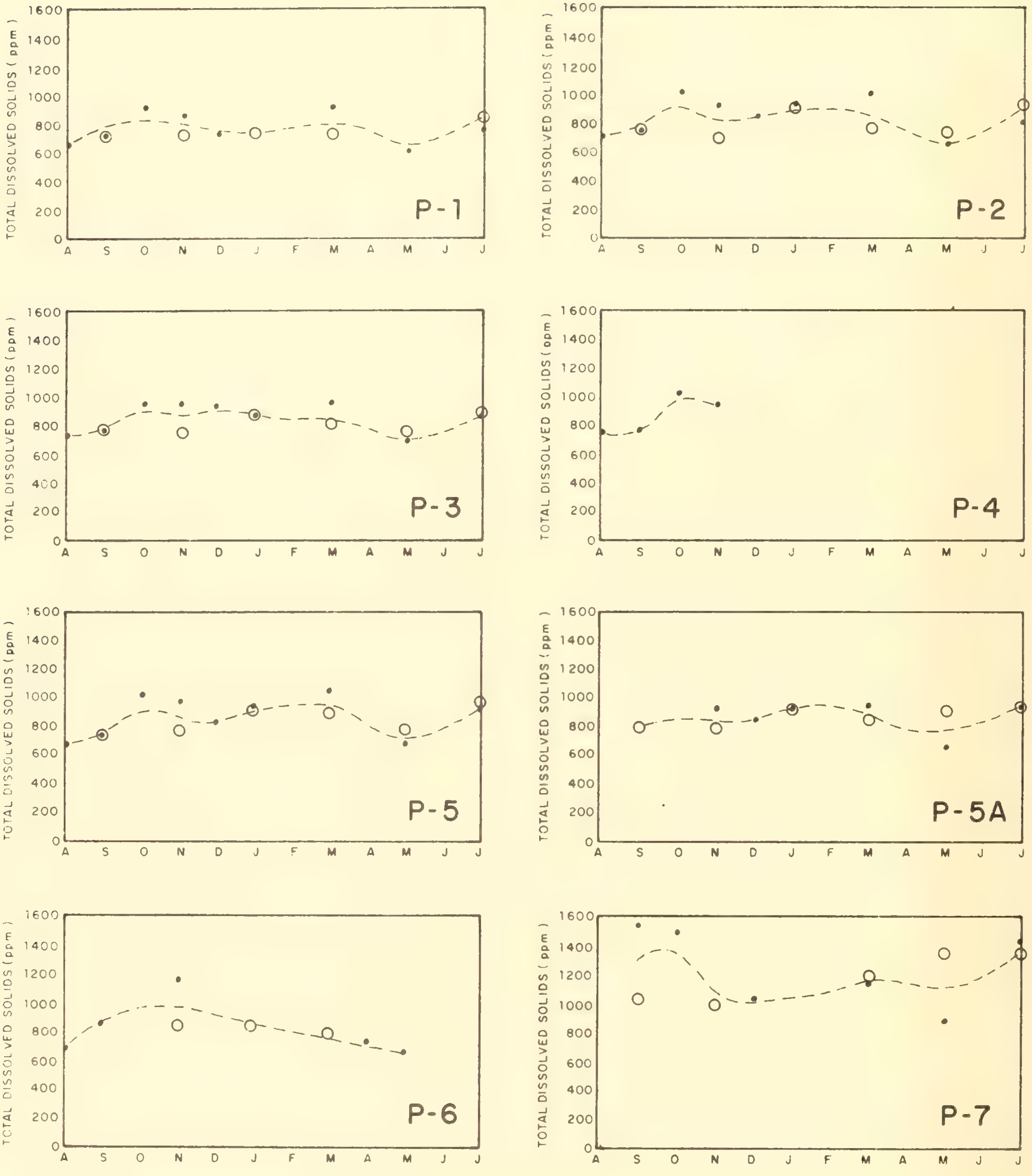

Figure 3-5-6
TOTAL DISSOLVED SOLIDS AT THE PICEANCE CREEK STATIONS AUGUST 1974 TO JULY 1976.

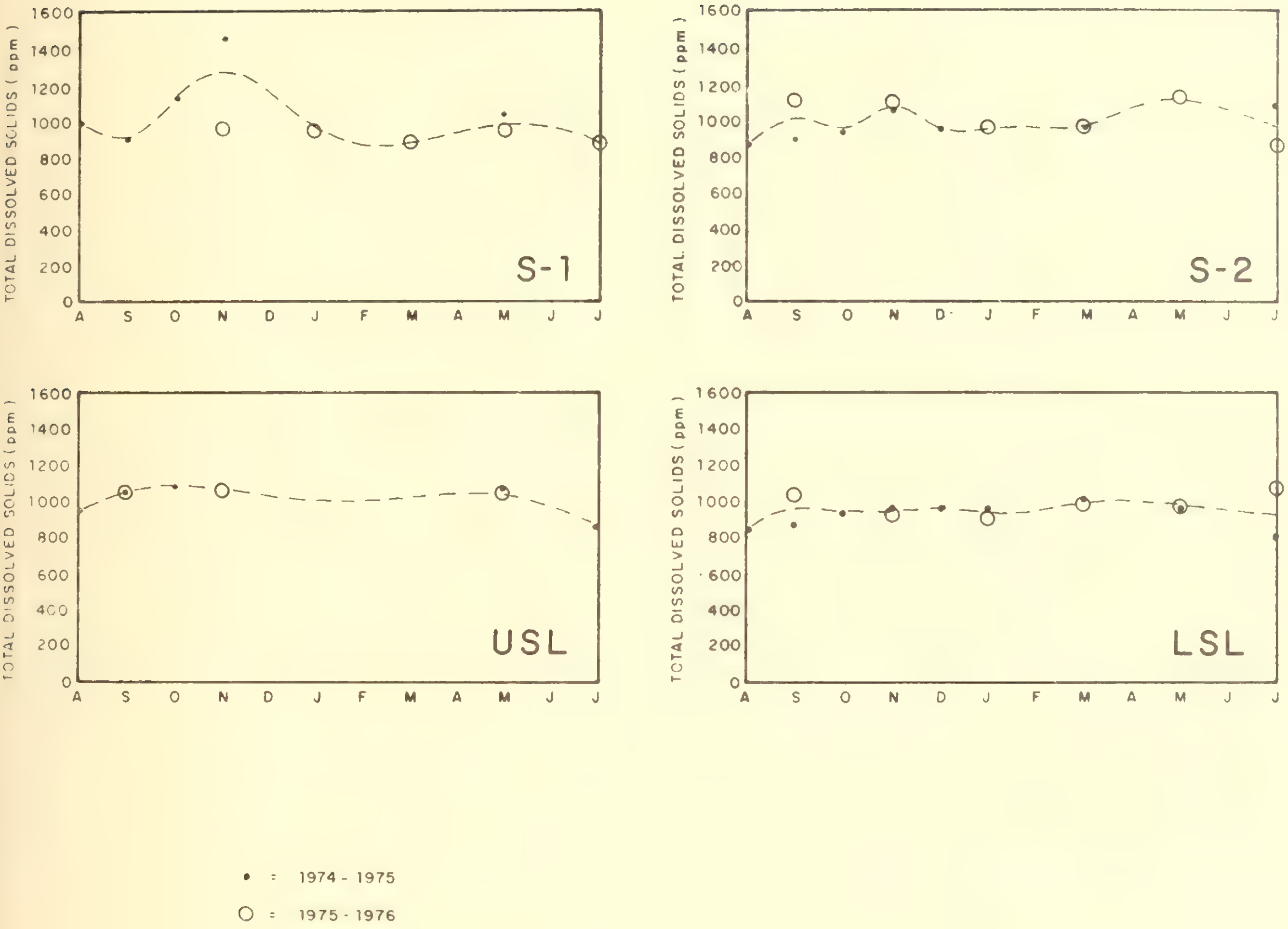

Figure 3-5-7
TOTAL DISSOLVED SOLIDS AT THE STEWART CREEK STATIONS
AUGUST 1974 TO JULY 1976.

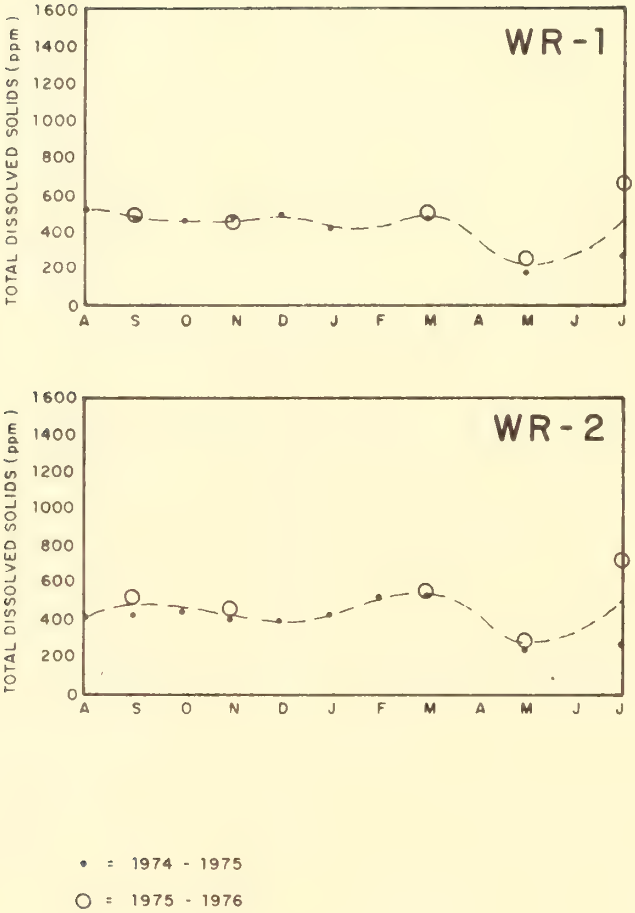

Figure 3-5-8
TOTAL DISSOLVED SOLIDS AT THE WHITE RIVER STATIONS
AUGUST 1974 to JULY 1976.

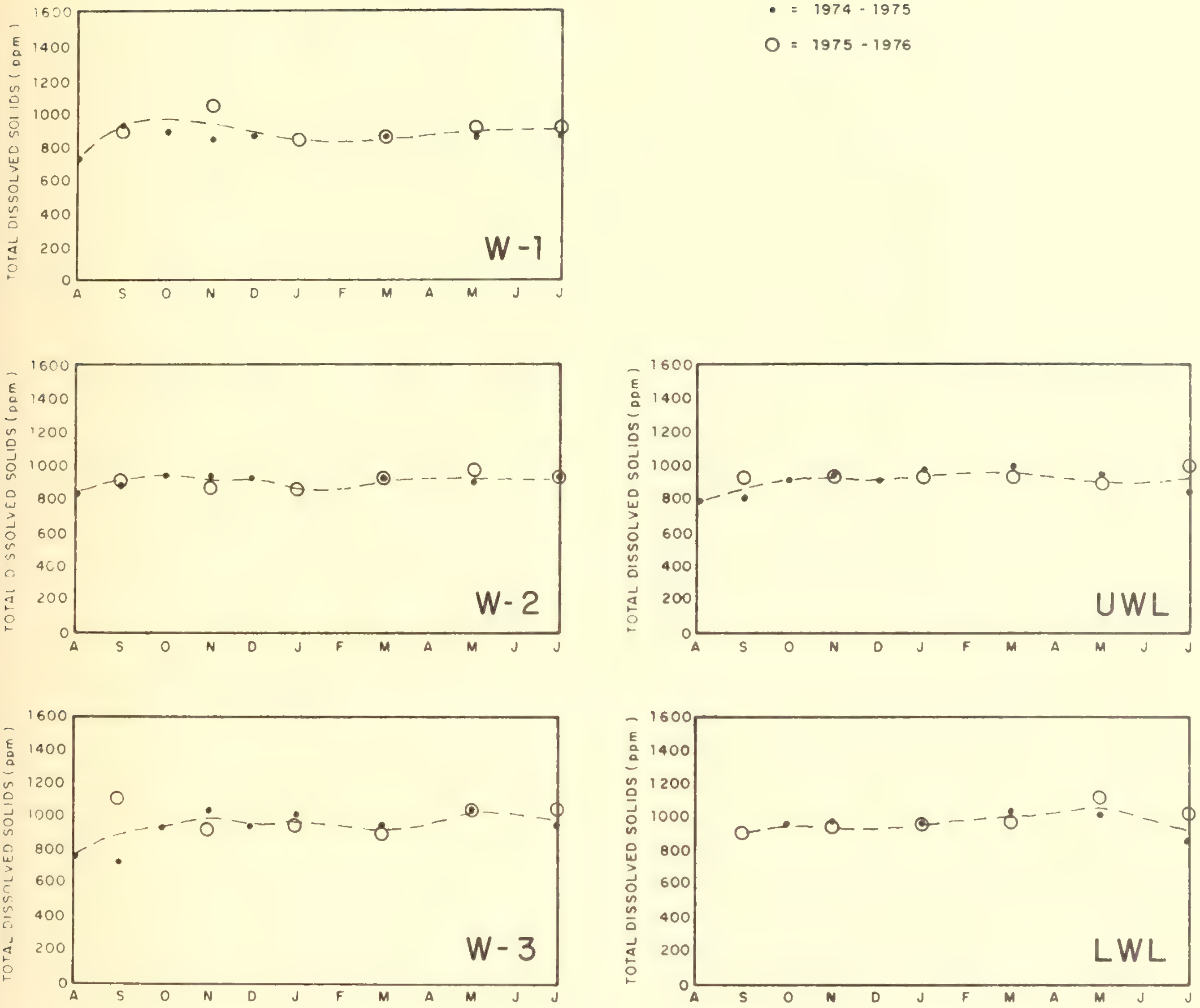

Figure 3-5-9
TOTAL DISSOLVED SOLIDS AT THE WILLOW CREEK STATIONS
AUGUST 1974 TO JULY 1976.

the best known are (a) Escherichia coli strains, which are usually, but not always of fecal origin, and (b) intermediate and Aerobacter aerogenes strains, which are usually, but not always, of soil, vegetable, or other non-fecal origin. E. Coli has been frequently proposed as a more specific and reliable indicator of fecal pollution than the broader coliform group.

The effect of the use of the coliform group instead of E. Coli as the basis for standards is to make the water relatively safer.

Coliform organisms may gain access to water from many sources, primary among which are excretions from human beings, animals, amphibians, and birds; surface run-off; and the multiplication of non-fecal forms on fibrous and vegetative substances in the water. Inasmuch as the bacterial flora vary from one source of supply to another, standards must not be interpreted too rigidly. A recommended practice is to rate each individual supply on the basis of frequent examinations, and to suspect at once any deviations from the usual quality.

Coliform counts in the streams examined reached high levels during certain times of the year. They exceeded recommended limits for aquatic life by greater than two-fold. Levels greater than 24,000/100 mg were reached in all streams. Undoubtedly cattle grazing and irrigation practices in the meadows along the streams contributed to these high levels.

Fecal coliforms also reached high levels in Piceance Creek, Willow Creek, and the White River (Appendix IV-B, Tables B-5-1a, B-5-1c, and B-5-1d).

3.5.5.1.10.2 Fecal Streptococci

The fecal streptococci include, in addition to the enterococci, the Streptococcus mitis-S, salivarius group, S. bovis, S. equinus, and an atypical group resembling the enterococci. Interest in the use of the fecal streptococci as indicator of potential pathogen contamination by intestinal wastes stems from the appearance that this group is characteristic of fecal pollution, that they do not multiply in surface waters, and that they rarely occur in surface soil or on vegetation not contaminated by sewage.

Surface drainage from agricultural land, feeding pens, and grazing areas can be expected to contribute substantially to the bacterial contamination of streams.

Fecal streptococci reached high levels in Piceance and Willow Creeks (Appendix IV-B, Tables B-5-1a and B-5-1c).

3.5.5.1.10.3 Pathogens

Except for the intestinal pathogens, most disease organisms do not gain access to water in any great numbers and can survive in it for only a limited time, so that their spread by this route has been rare.

The survival of disease organisms is dependent on many factors, both physiological and environmental. Among the more important physiologically are (a) their ability to form resistant spores, (b) reaction to heat, cold, and chemicals, and (c) competition with other organisms. Factors that are environmentally significant include oxygen supply, pH, temperature, sunlight, nutrient supply, sedimentation, dilution, and the antibiotic and competitive activity of other organisms.

No pathogens were detected at the stations examined for disease pathogens during the study.

Ten of the thirty-one parameters measured during the water quality studies exceeded recommended limits for aquatic life at some time during the course of the study (Table 3-5-1). Habitat in Piceance Creek and tributary streams ranges from poor to good depending on water quality, substrate, cover areas, physical characteristics, etc. At certain times the system is able to support significant numbers of fish and aquatic species. Salmonids spawn in the streams. However, the stream as it now exists is of marginal quality and further degradation of water quality or habitat could have a detrimental effect.

Sediments in the streams fluctuated seasonally. Deposition and erosion of sediments occurred during low flows and periods of high runoff respectively. Grain size analyses from sampling stations were graphed (Appendix IV-B, Figures B-5-1 to B-5-14).

In Piceance Creek, stations in the upper portions of the creek had the highest levels of fine sediments in May with low levels in July. Fine sediments began accumulating in the spring and reached high levels during the peak runoffs (May). By summer during low flow periods (July) fine sediment levels were reduced considerably over levels in May. Low levels continued through fall and winter and began accumulating again in spring (Appendix IV-B, Figures B-5-1 to B-5-4). In the lower portions of Piceance Creek, sediments were comprised of fine material throughout the year (Appendix IV-B, Figures B-5-1 to B-5-4). Silt levels were higher at downstream portions of Piceance Creek than at upstream portions in summer months.

The downstream portions of Piceance Creek do not have gravel substrates which are exposed upon flushing of fine sediment as is the case in the upper portions of Piceance Creek.

Stewart Creek has a low flow compared to Piceance Creek. Runoff levels are smaller and sediment and silt levels are fairly constant throughout the year (Appendix IV-B, Figures B-5-5 to B-5-7). There are no pronounced seasonal fluctuations as are found in Piceance Creek.

Willow Creek showed seasonal changes at the downstream station, with greater silt levels in spring and fall. The upstream portions of Willow Creek were fairly constant year round (Appendix IV-B, Figures B-5-8 to B-5-12).

Sediment levels in upper and lower Stewart and Willow Lakes were fairly constant year round (Appendix IV-B, Figures B-5-6, B-5-7, B-5-11, and B-5-12).

Sediment levels in the White River did not show the marked fluctuations exhibited in Piceance Creek (Appendix IV-B, Figures B-5-13 and B-5-14).

A spectrographic screen analysis for heavy metals was conducted in July 1975 for sediment samples from selected stations (Appendix IV-B, Table B-5-2). All metals detected occurred in generally low concentrations.

3.5.5.2 Plankton

Plankton collected during the study were not analyzed. Much of the plankton in streams may be derived from the scouring of periphyton from the stream bed. Generally periphyton are the predominant primary producers in streams and as such are an excellent indicator of water quality with the added advantage that being attached, unlike plankton, they respond to changes at the site. Plankton samples collected contained few organisms relative to periphyton samples. In addition, because of the rapid fluctuations in plankton numbers and their short life histories, bimonthly sampling would make it difficult to study changes in the plankton populations. For these reasons, plankton collections were not analyzed or studied.

However, an effort was made to assess phytoplankton production in the lakes studied. All lakes were spring fed with an outlet to adjacent streams. Light and dark bottle measurements were made of dissolved oxygen levels to estimate plankton productivity in the lakes (Appendix IV-B, Table B-5-3). All lakes were shallow with clear water. In many cases, there was little difference between light and dark bottle D.O. values when incubated for 8 to 24 hours. This could have been the result of light inhibition or little, if any, plankton in the lakes. At times where there was a significant difference between light and dark bottle values, productivity estimates were computed (Table 3-5-2). The highest values of gross and net production were found in Lower Willow Lake in spring and summer (Table 3-5-2). Gross production reached 288.75 mg C fixed/M^3 in July. Net production reached 213.75 mg C fixed/M^3 in March. In Lower Stewart Lake the highest gross production was 202.50 mg C fixed/M^3 in January. The highest net production was 150.0 mg C fixed/M^3 in the same month. The lowest values were in Upper Stewart Lake. However, it was not sampled in all months because of ice and low water level.

Table 3-5-2 LIGHT AND DARK BOTTLE PRODUCTIVITY ESTIMATES[1] FOR STEWART AND WILLOW LAKES, JULY 1975 - JULY 1976

Lake Station		July 1975		September 1975	November 1975	January 1976	March 1976	May 1976	July 1976
U.S.L.	N[2]	0.28		----				0.42	
	G[3]	0.49[6]	0.00[7]	----				----	
	GP[4]	183.75[6]	0.00[7]	----				----	
	NP[5]	105.0						157.5	
L.S.L.	N	0.10		0.14	0.00	----	----	0.45	0.00
	G	0.56[6]	0.21[7]	0.14	0.14	0.00	----	0.56[8]	0.63
	GP	210.00[6]	78.75[7]	52.50	52.50	----	----	210.00	236.25
	NP	37.5		52.5	----	----	----	168.75	----
U.W.L.	N	----		----	----	0.40	----	0.10	----
	G	----	----	0.01	0.47	0.54	----	0.18[9]	----
	GP	----	----	3.75	176.25	202.50	----	67.50	----
	NP			----	----	150.0		37.5	
L.W.L.	N	0.45		----	0.07	----	0.57	0.53	0.22
	G	0.70[6]	0.77[7]	----	----	0.14	0.57	0.21[9]	0.42
	GP	262.50[6]	288.75[7]	----	----	52.50	213.75	78.75	157.50
	NP	168.75		----	26.25	----	213.75	198.75	82.5

[1] APHA (1975)

[2] N = Net Photosynthesis (light bottle DO - initial DO) mg/1

[3] G = Gross Photosynthesis (light bottle DO - dark bottle DO) mg/1

[4] GP = Gross Production (mg C fixed/m^3)

[5] NP = Net Production (mg C fixed/m^3)

[6] 8 Hr.

[7] 24 Hr.

[8] 21 Hr.

[9] 22 Hr.

3.5.5.3 Periphyton

Periphyton samplers were difficult to keep installed year round at some stations. Samplers were carried away in flood waters during periods of high runoff at certain stations. This was especially true of Piceance Creek and the White River. Some samplers were buried by silt at times. In winter, ice conditions destroyed some samplers. In addition, some losses were incurred due to cattle and vandalism.

In spite of some of the difficulties mentioned above which prevented a continuous bimonthly record at all stations, adequate information was obtained to examine seasonal abundance and productivity of periphyton species.

Periphyton species identified in collections were comprised of green algae, diatoms, blue-green algae, and euglenids. Diatoms were the most numerous followed by green algae and blue-green algae. Also vascular plants were identified (Appendix IV-B, Table B-5-4).

In Piceance Creek, the greatest number of species was found in summer (July) and fall (September - November). This was generally true in the other streams studied also. However, in stretches of stream fed by springs where temperatures did not reach the freezing level in winter, in some cases species numbers were at higher levels in winter than in summer. Some areas of Piceance which did not freeze in winter (P-2) also had a higher number of periphyton species in winter months (Appendix IV-B, Table B-5-5). The White River could not be sampled in winter or spring due to ice and flooding. The highest numbers occurred in fall (Appendix IV-B, Table B-5-5).

Productivity estimates were made based on ash free dry weight produced per square meter per day (Table 3-5-3). Values fluctuated seasonally. In Piceance Creek the highest productivity was in summer and fall. Generally, the lowest levels of production were found at the downstream stations. In Stewart and Willow Creeks, productivity was also highest in summer and fall. In Stewart Creek, the upstream station had the highest productivity. In Willow Creek, the upstream stations also had the highest production (Table 3-5-3). The periphyton productivity values found in this study are within the range of values determined by Sládecek and Sládecková (1964) and Castenholz (1960).

Diatoms present within the streams were examined in light of Lowe's (1974) compilation from numerous workers of ecological data on distribution of freshwater diatoms. In Piceance Creek, almost all diatoms identified to species are common to waters with pH of 7 or higher. A few are common to waters with a pH of 7 or slightly below. The species represented in Piceance Creek are all found in eutrophic (high nutrient concentrations) waters, with small amounts of salt (less than 500 mg/1). They are characteristic of waters where oxidation of biodegradable compounds are complete with high

Table 3-5-3 PERIPHYTON PRODUCTIVITY[1] ESTIMATES FOR PICEANCE BASIN STATIONS, MAY 1975 - JULY 1976

	Months							
Station	May	July	Sept	Nov	Jan	March	May	July
P-1		.1136*	.7964	.0071				
P-2		.0852	.0520	.0074				
P-3		.1429	.4936	.0092	.0614	.3029	.8425	.0232
P-5		.2906	.1832*	.0255				
P-5A			1.9059	.9596				.4528
P-6	.0192	.0258	.0116	.0067	.0070	.1698	.0142	.0339
P-7	.0088	.0473	.2459	.0235**			1.0738	.0310
S-1	.1310	.0276	.0089	.1380	.0567	1.375	2.4874	
S-2	.0063	.0708	.0164				.7598	.0247
USL		.0283	.0249***	.1676				
LSL[2]			H =.2866 V =.0930	H =.2189 V =.1196	H = .1584 V = .2301**	H=.4601 V=.2575		
W-1	.0964		.0418	.2659			3.2297*** 2.0331	1.9171
W-2							4.1507	1.5682
W-3	.0215		.0758	.1648	.1025		.1411	.2365
UWL			.0360	.2780	.7124	1.8139	.3658**	.0640
LWL			.0641	.0713	.0594	.1129	.1819	.0165
WR-1			.4693	.1383**				
WR-2			.1893	.0613**			4.4029	

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1. Grams ash-free weight/m^2/day (average of three replicates exposed for approximately 30 days).
2. H = Horizontal slide, V - Vertical slide.

* One slide only
** Two slides only
*** Exposed for two months

levels of inorganic nutrients or with weak pollution where nitrogen is in the form of ammonia compounds. They are generally characteristic of small or larger streams or ponds. The vast majority of the species found in Piceance Creek are periphytic (occurring on substrates). A few are sometimes found suspended in the water. Seasonal distribution was variable, but the majority of the species reach maximum numbers in spring, summer and/or fall. Most are cold water forms or occur over a temperature range of 15°C or greater.

The species identified from Stewart and Willow Creeks were indicative of the same characteristics mentioned above for Piceance Creek.

In the White River similar species were collected with comparable environmental requirements to those found in other streams.

In the lakes studied, the species were similar to those found in the streams. Water quality was similar to the values found in the streams studied.

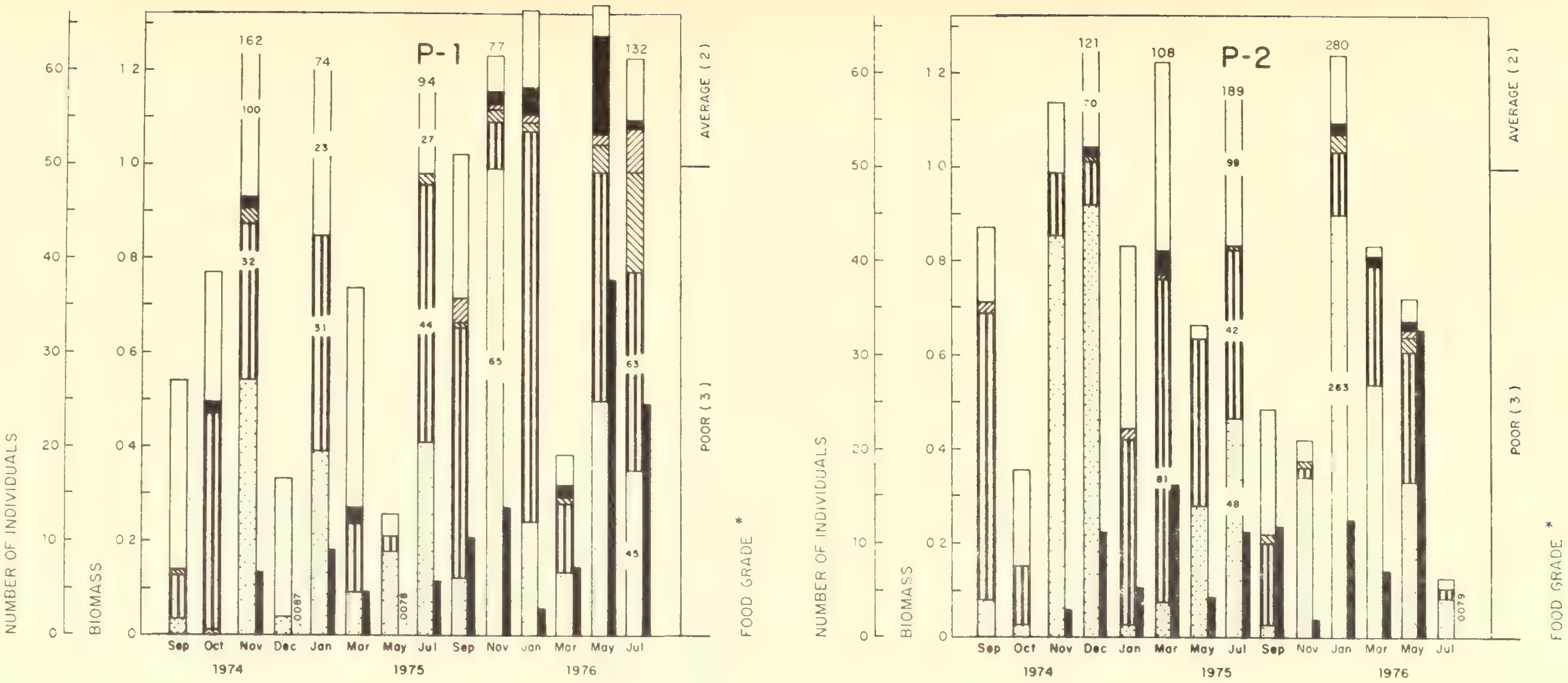
3.5.5.4 Benthos

Aquatic invertebrates collected from all stations were comprised of annelids, arthropods, and molluscs (Appendix IV-B, Table B-5-6). Arthropods were the most numerous. For each station, species diversity, mean biomass, equitability (Lloyd and Ghelardi 1964), redundancy (Harrel and Duplechin 1976), and dispersion values were calculated. Samples were identified to the lowest taxon possible (Appendix IV-B, Table B-5-7).

The total number of individuals by order and mean biomass was graphed relative to Lagler's (1956) stream classification for suitability of the station to support fish populations.

Based on Lagler's (1956) food grade categories, all stations were in the poor food grade most of the time (Figures 3-5-10 to 3-5-13). Stations P-3, S-1, USL, LSL, W-1, W-2, and UWL did reach the average food grade category on some occasions. No stations were in the exceptional food grade category. The greatest mean biomass usually was found in March and May at most stations. Sometimes high levels continued into July. The peak numbers of aquatic invertebrates occurred at various times of the year. High numbers were found in spring, summer, fall and, in some cases, winter (Figures 3-5-10 to 3-5-13).

In Piceance Creek, dipterans and ephemeropterans were the dominant organisms followed by ogligochaetes. Chironomid larvae were the most abundant dipteran species. Chironomids were most abundant in summer and fall and declined in numbers in late winter and spring (March-May). Simuliids were present in large numbers during summer (May-September). Simuliids were the second most abundant dipteran species. Tipulids were present in low numbers throughout



NOTE

* Stream classification based on Lagler, 1956

▮ = Biomass

☐ Diptera

■ Plecoptera

▨ Tricoptera

▨ Coleoptera

▥ Ephemeroptera

☐ other

Figure 3-5-10
BENTHIC INVERTEBRATE NUMBERS[1] AND BIOMASS[2] FOR
PICEANCE CREEK STATIONS
SEPTEMBER 1974 TO JULY 1976

[1] Number / sq ft (average of 3 replicates)

[2] Grams / sq ft (average of 3 replicates)

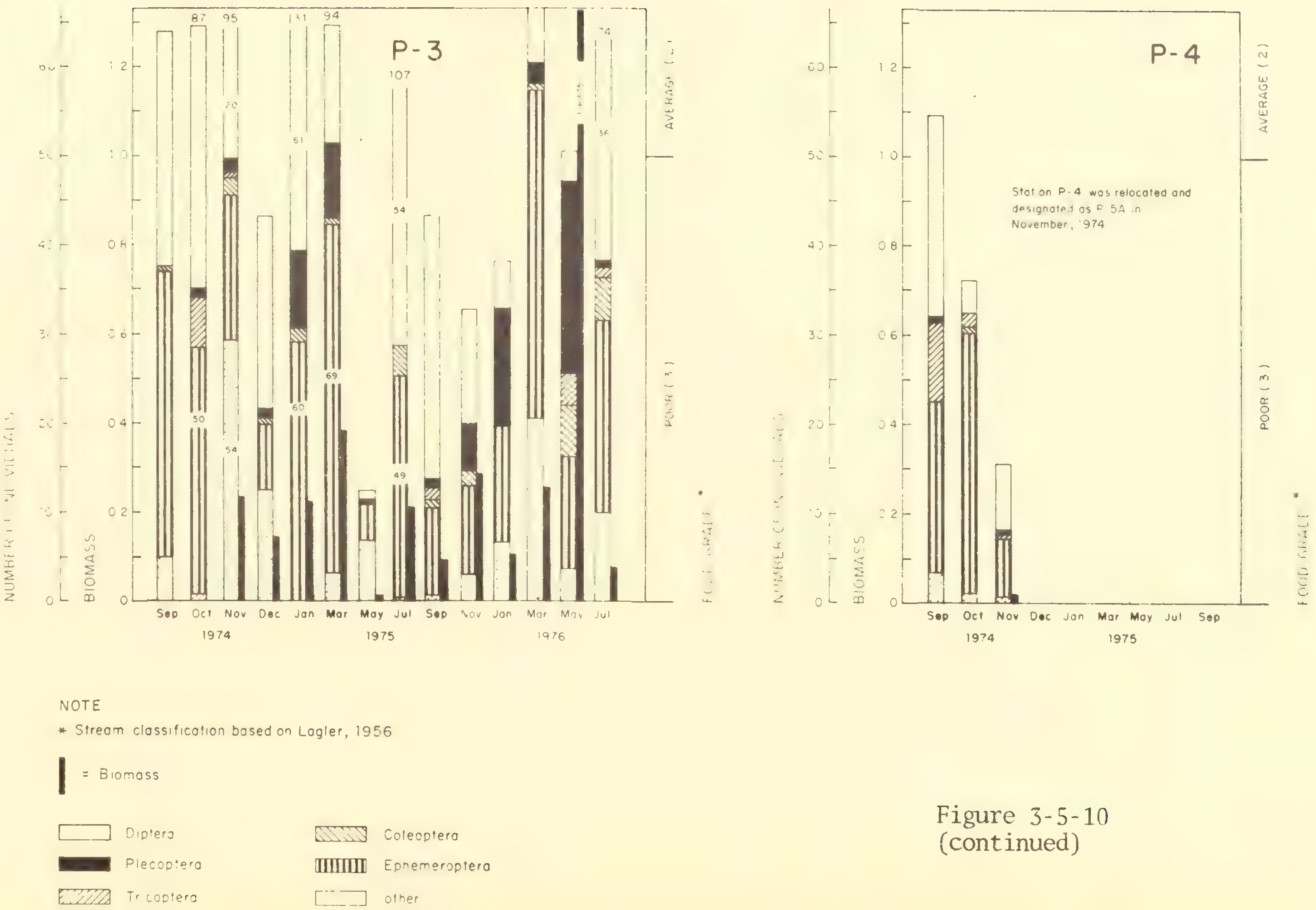


Figure 3-5-10
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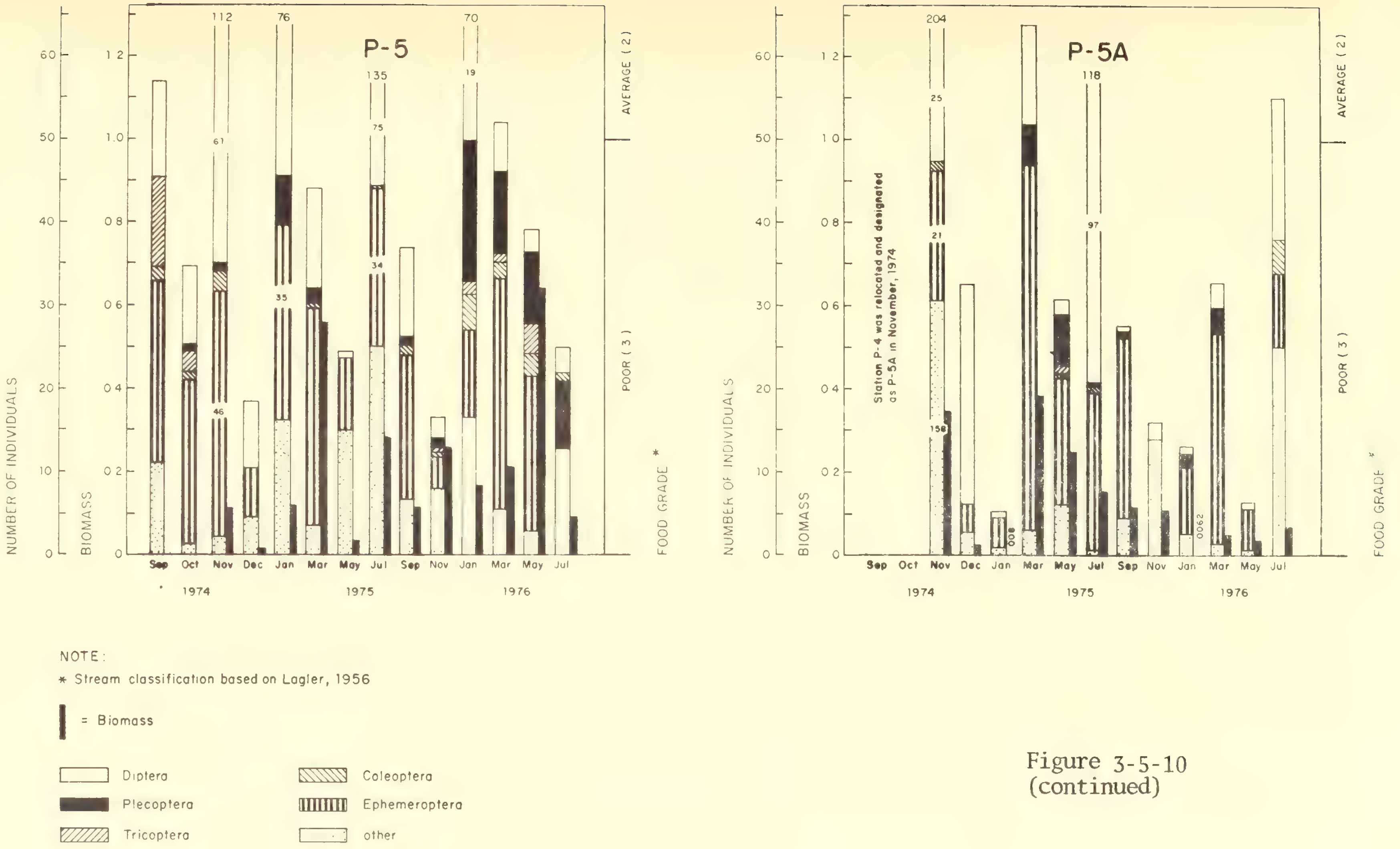
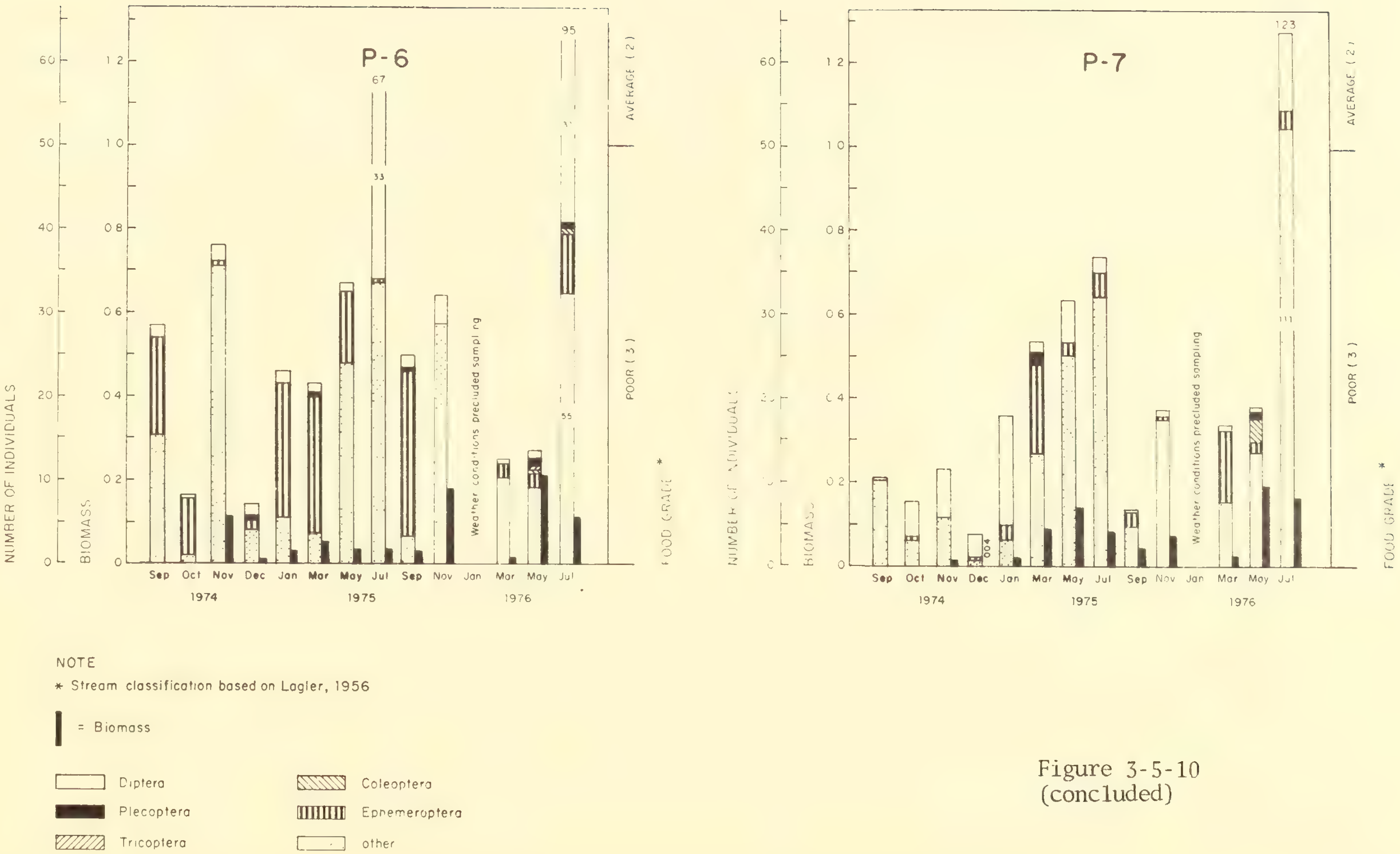


NOTE:
* Stream classification based on Lagler, 1956

Figure 3-5-10
(continued)



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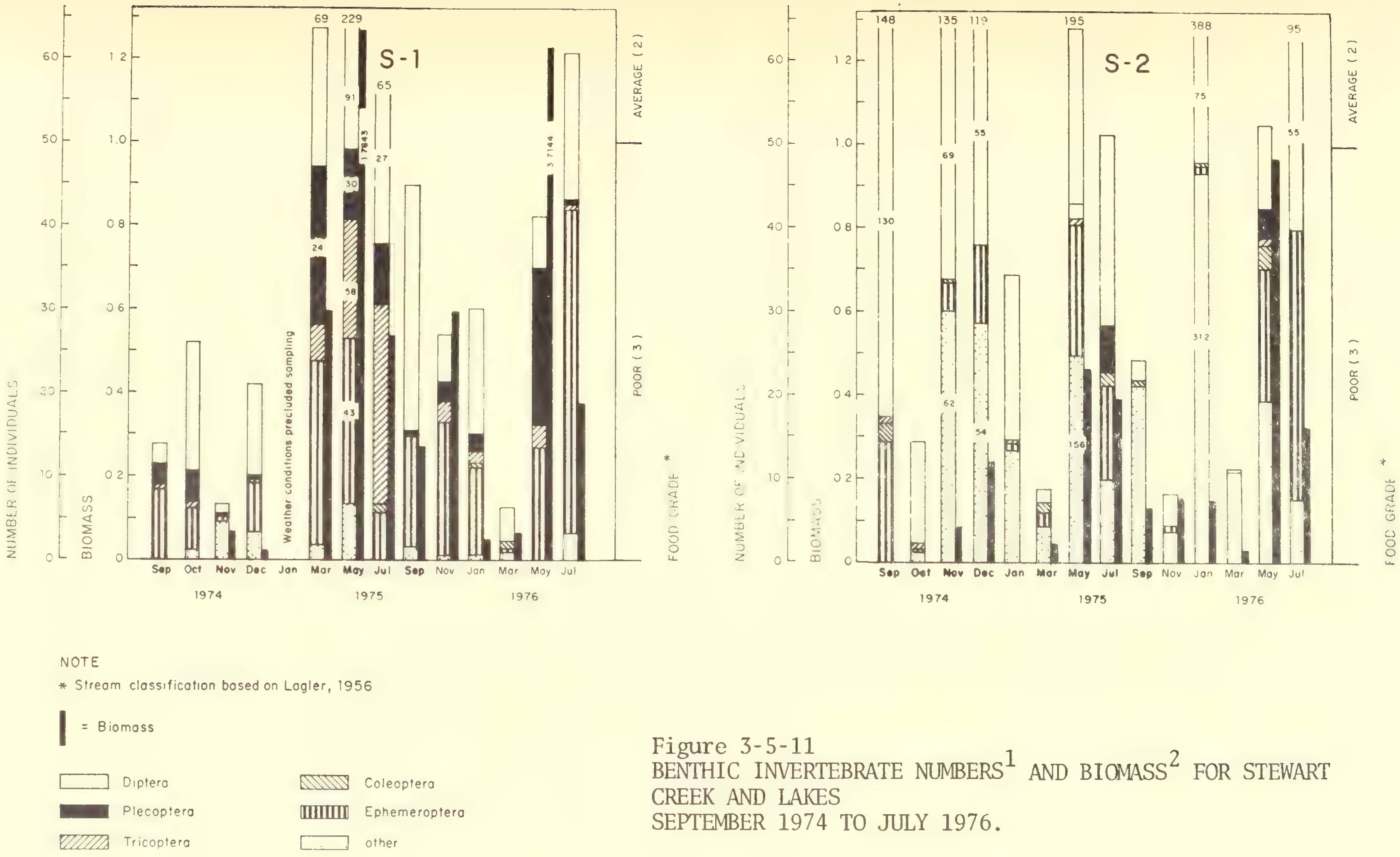


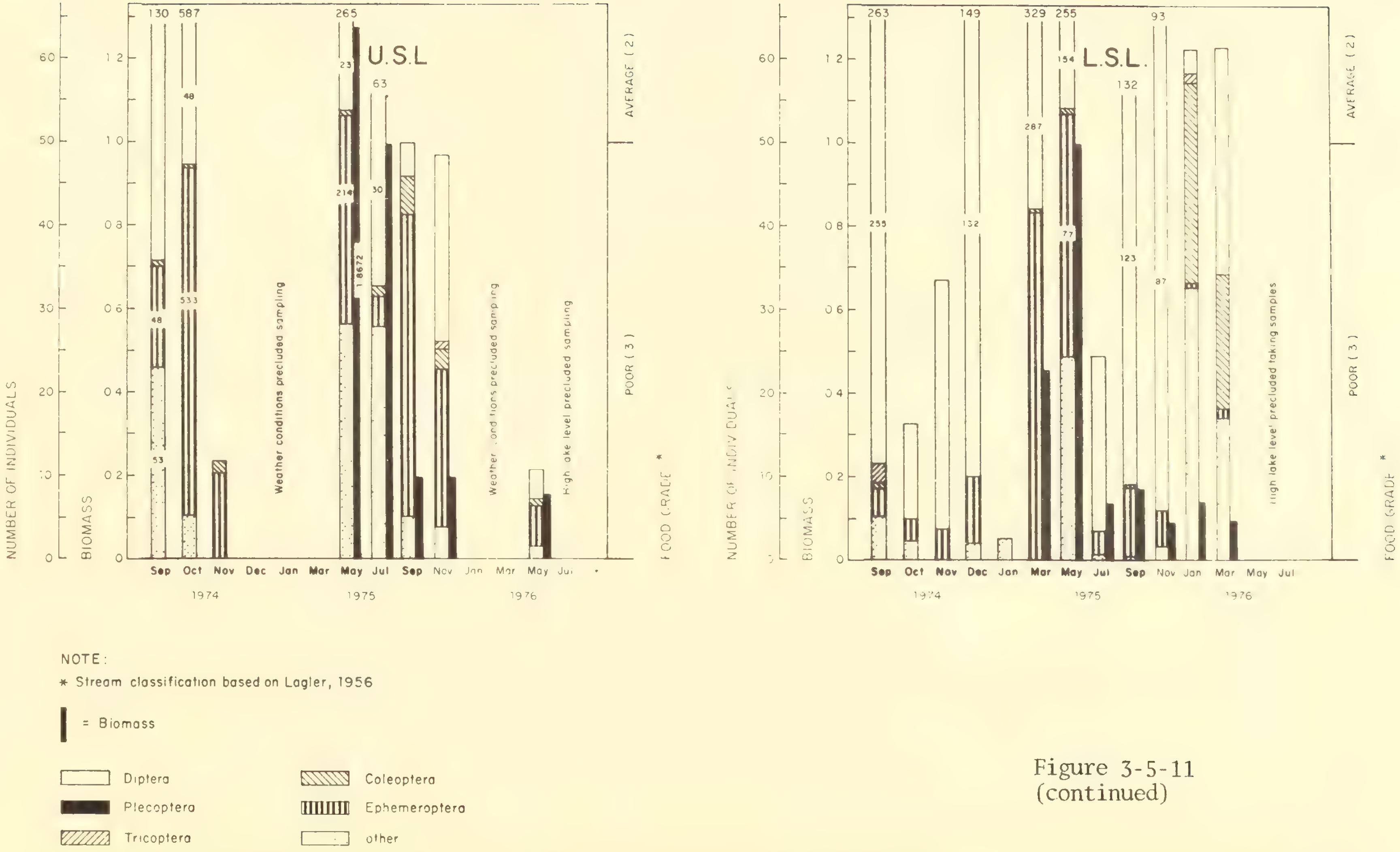
NOTE

* Stream classification based on Lagler, 1956

Figure 3-5-11
BENTHIC INVERTEBRATE NUMBERS[1] AND BIOMASS[2] FOR STEWART CREEK AND LAKES
SEPTEMBER 1974 TO JULY 1976.

[1] Number/sq ft (average of 3 replicates)

[2] Grams /sq ft (average of 3 replicates)



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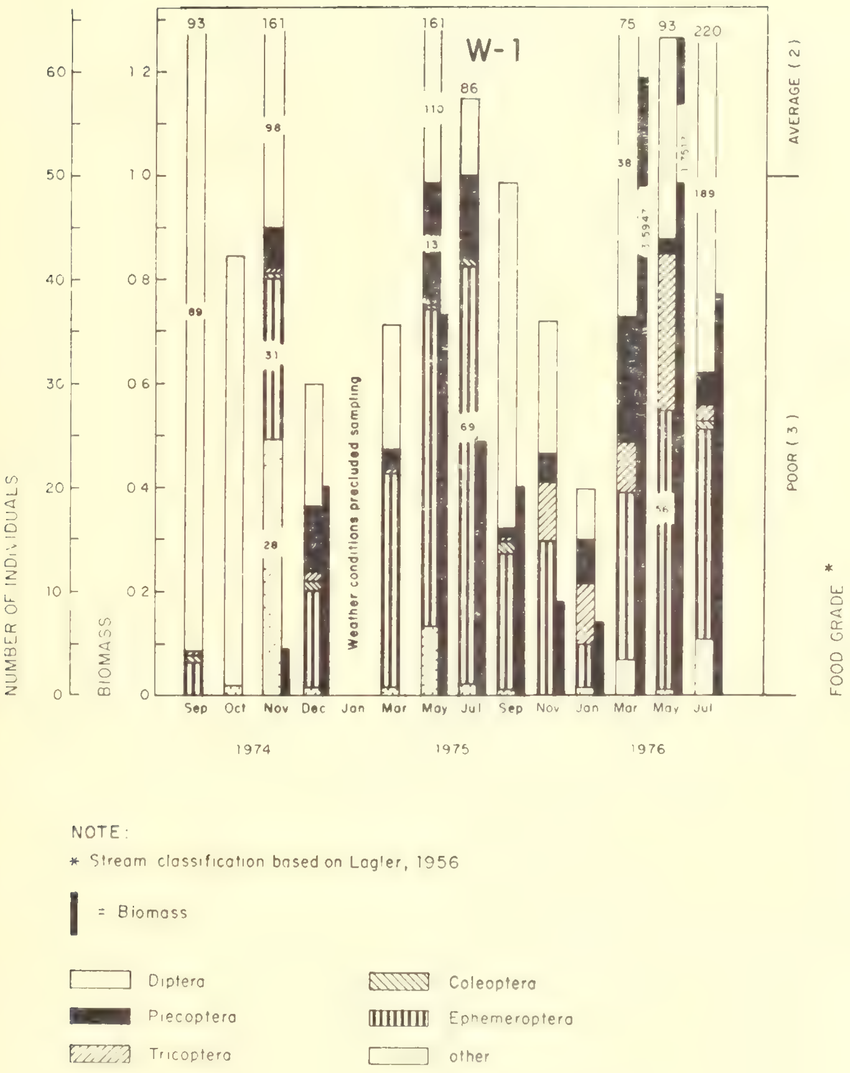

Figure 3-5-12
BENTHIC INVERTEBRATE NUMBERS[1] AND BIOMASS[2] FOR WILLOW CREEK AND LAKES
SEPTEMBER 1974 TO JULY 1976.

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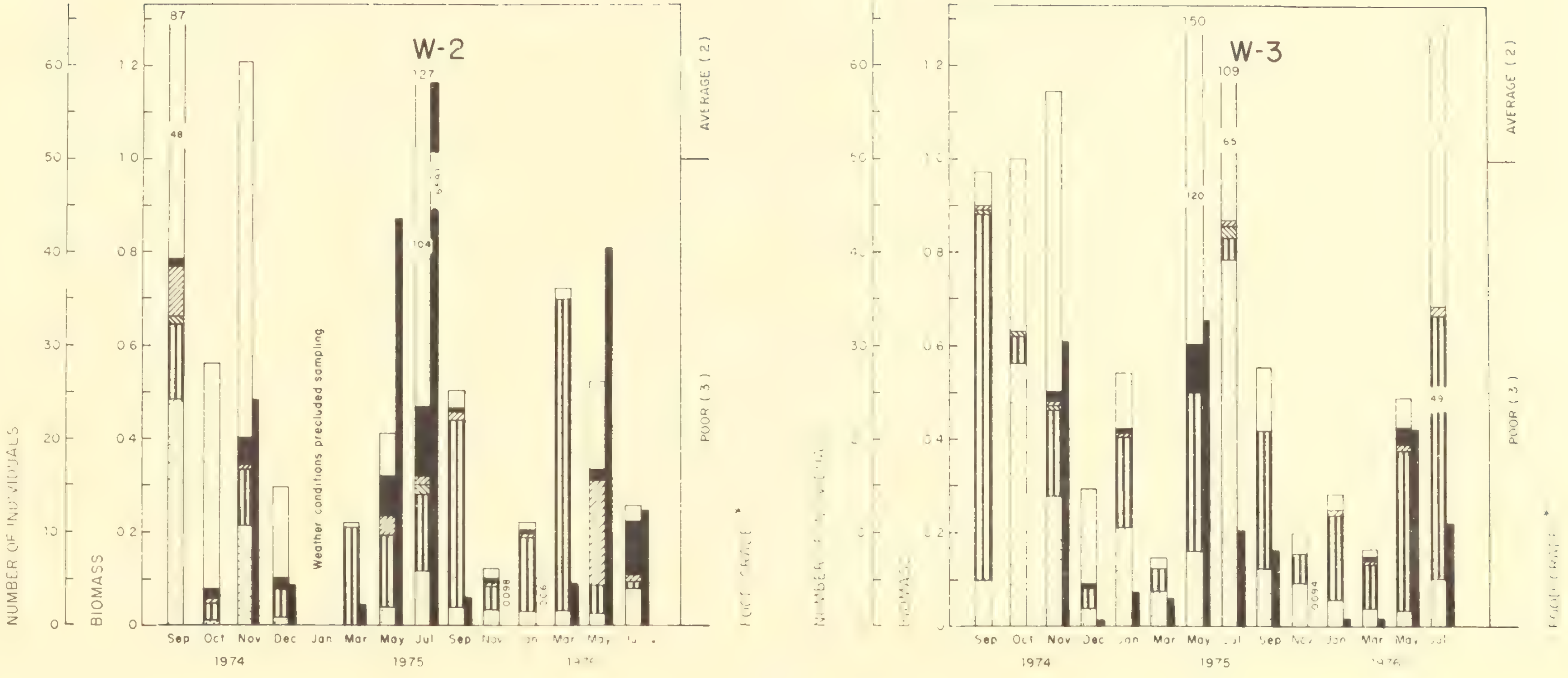
[1] Number / sq. ft (average of 3 replicates)

[2] Grams / sq. ft (average of 3 replicates)



NOTE

* Stream classification based on Lagler, 1956

Figure 3-5-12
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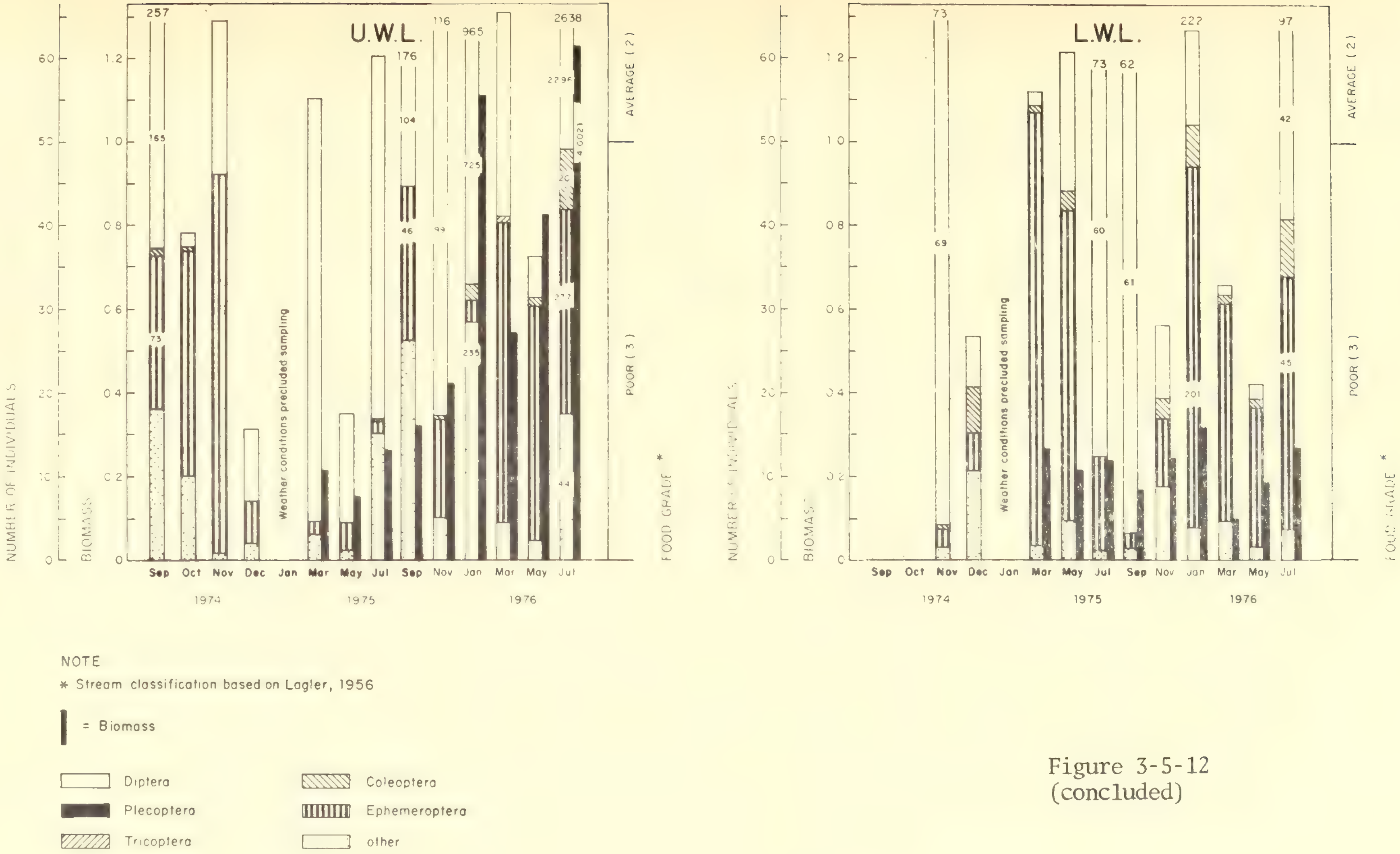

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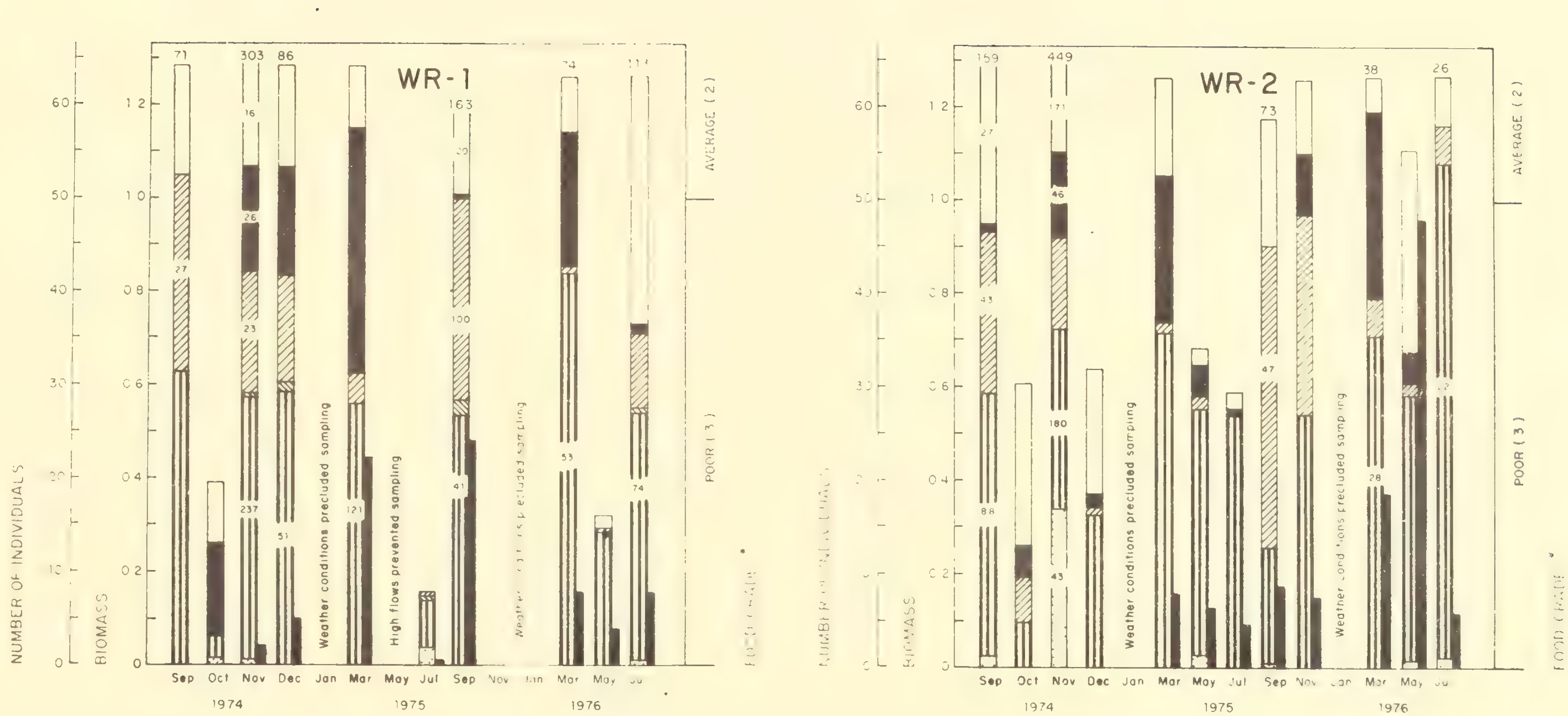

NOTE

* Stream classification based on Lagler, 1956

▮ = Biomass

□ Diptera
■ Plecoptera
▨ Tricoptera
▧ Coleoptera
▥ Ephemeroptera
□ other

Figure 3-5-13
BENTHIC INVERTEBRATE NUMBERS[1] AND BIOMASS[2] FOR THE WHITE RIVER
SEPTEMBER 1974 TO JULY 1976.

[1] Number / sq ft (average of 3 replicates)
[2] Grams / sq ft (average of 3 replicates)

the year. Dipterans were fairly uniform numerically in taxonomic composition from stations P-1 to P-5A. Dipterans declined at Stations P-6 and P-7, but remained the most abundant species at these stations. Plecopterans were most abundant during winter and spring (January - May) but were not present in high numbers at any time during the year. They were distributed from Stations P-1 to P-5A with few being taken at stations P-6 and P-7. Trichopterans were most abundant in summer months (May-September) although not present in high numbers. Their spatial distribution was similar to that of Plecopterans. Ephemeropterans were present in high numbers year round. They were most abundant in winter. Baetis was the most abundant ephemeropteran and Ephemerella was the second most abundant.

Ephemeropterans were found from Stations P-1 to P-7. Heavy concentrations occurred between Stations P-1 and P-5A. Some were present in small numbers year round from Station P-1 to P-5A. None were present at Stations P-6 and P-7. Oligochaetes were abundant in summer months. They significantly increased the number of invertebrates found in the summer and fall. The numerical abundance of all invertebrates was low at Stations P-1, P-6, and P-7 in Piceance Creek. The highest values were found at Stations P-2 and P-3 with a decline in numbers at Stations P-5 and P-5A. During summer months, the numerical values were fairly consistent from Stations P-1 to P-5A with reduced numbers at P-6 and P-7.

In Stewart Creek, dipterans were most abundant during the summer months. Chironomids were the most prominent group. Numbers declined by fall and remained low in winter. Simuliids were abundant in summer but disappeared in winter months. Dipterans were abundant in Lower Stewart Lake year round. Plecopterans increased during spring and early summer months, but were at low levels during the rest of the year. Isoperla was the most abundant plecopteran species. Station S-1 had the highest level of plecopteran species during the year, while S-2 had some during late spring and early summer. No plecopteran species were taken from the lakes. Trichopteran species were generally present in low numbers. Peak months were March to July. Station S-1 had the greatest number of trichopteran with very low numbers occurring at Station S-2 and in the lakes (LSL and USL). Ephemeropterans were fairly abundant in Stewart Creek with Baetis being the dominant species. They were most abundant in spring and early summer. Callibaetis was the dominant species in the lakes. Coleopterans were most abundant in spring and summer. Abundance was similar at all stations. Upper Stewart Lake supported the greatest number of coleopteran species. Other groups found in Stewart Creek included oligochaetes, amphipods, and odonata. Oligochaetes and odonates are present in summer months. Amphipods were abundant in spring and fall at Stations S-1, S-2 and LSL. The greatest concentration of oligochaetes occurred in summer at Station S-2.

In Willow Creek, dipterans occurred year round with a slight decrease in numbers in winter months. Chironomids were the most abundant dipterans. Tipulids also occurred year round. Stations

W-1, W-3, and UWL supported good populations of dipterans. Plecopterans were present in low numbers. The highest levels of plecopterans occurred in spring and early summer. Isoperla was the most abundant species. No plecopterans were taken from lake stations. Trichopterans were found only at creek stations. They were most numerous during winter and spring. Ephemeropterans were found in the creek and lake stations. They occurred year round in large numbers. Baetis was the dominant species in the creek and Callibaetis was the dominant species in the lakes. They were more abundant in LWL than UWL. Coleopterans were taken in the creek and lakes. Agabinus was the dominant species. They were not present in large numbers at any time of the year, but the greatest abundance occurred in winter in Lower Willow Lake. Oligochaetes occurred at all stations year round. They were especially abundant in Upper Willow Lake.

In the White River, low numbers of dipterans were found. Chironomids, the major dipteran species, occurred throughout the year. Plecopterans were most abundant in winter. Isoperla was the dominant species. Trichopterans were most abundant in fall. Hydropsyche was the dominant species. Ephemeropterans were abundant from fall through spring. Baetis and Ephemerella were dominant species. Coleopterans were present in very low numbers in the White River, as were oligochaetes, amphipods, and odonata. The two White River Stations were very similar with respect to benthic fauna.

In an effort to examine variations in the benthic fauna between stream stations, species diversity, equibility, and redundancy values were computed for each month for all stations (Table 3-5-4). Theoretically, the diversity index provides an estimate of the complexity of the biological community and reflects structural and organizational features which lend it overall stability. It is felt that the greater number of species in a community, the more complex the energy flow pathways become. If any one pathway were eliminated, no great harm to the system would result, since other similar energy pathways exist. The system thus maintains its stability. In a very simple community of few species, on the other hand, removing only one energy pathway could cause a loss of stability in the community.

The diversity index, H', has two components: 1) number of species, and 2) the proportion (evenness) of individuals among species, both of which increase diversity. Intuitively, one would accept that a sample of ten species is more diverse than a sample of two species; therefore, H' would increase. The higher the H' value the greater the number of species and/or evenness component, and the more stable or complex the community. It also follows that low diversity may indicate a simple community or one suffering from some environmental perturbation. The range of the diversity index varies from zero to any positive number (usually nine is about maximum) (Wilhm 1970). A value of zero is obtained when all organisms belong to the same species. Wilhm (1970) reviews numerous workers' findings with regard to species diversity values for bethic macroinvertebrates in

Table 3-5-4 BENTHIC INVERTEBRATE SPECIES DIVERSITY (D), EQUIBILITY (E) AND REDUNDANCY (R) VALUES FOR PICEANCE BASIN STATIONS SEPTEMBER 1974 - JULY 1975

		Stations																		
Month		P-1	P-2	P-3	P-4	P-5	P-5A	P-6	P-7	S-1	S-2	USL	LSL	W-1	W-2	W-3	UWL	LWL	WR-1	WR-2
9/74	D	1.66	2.08	2.60	2.75	3.26		1.46	1.01	1.67	2.01	1.98	0.44	1.97	3.15	1.26	1.36		1.81	1.81
	E	.44	.62	1.14	.81	1.07		.60	1.00	.80	.50	.55	.25	.55	1.00	.27	.37		.66	.33
	R	.55	.46	.21	.29	.24		.51	.37	.33	.42	.40	.89	.40	.15	.73	.56		.44	.53
10/74	D	1.51	1.60	2.06	1.38	2.42		1.60	1.19	2.45	2.12	.60	1.42	2.20	2.33	1.75	1.34		1.85	1.69
	E	.80	.80	.55	.37	.58		.80	1.00	.70	.75	.28	.60	1.00	.77	.66	.50		.71	.66
	R	.38	.38	.33	.57	.40		.30	.36	.33	.32	.80	.50	.15	.29	.32	.53		.29	.43
11/74	D	2.21	1.40	2.47	2.46	2.20	1.29	.44	1.42	2.02	2.44	.51	.49	2.64	2.44	3.00	.87	.41	2.88	2.82
	E	.50	.42	.44	.80	.54	.25	.50	.75	.62	.41	1.00	.66	.60	.50	.78	.66	.25	.55	.52
	R	.40	.59	.45	.19	.39	.66	.86	.36	.23	.41	.59	.52	.33	.38	.26	.12	.87	.41	.34
12/74	D	.67	1.47	2.37		2.12	1.16	2.02	1.84	1.98	2.34		.54	3.02	2.65	1.37	1.46	1.99	2.02	2.88
	E	.50	.36	.46		.75	.37	.62	1.00	.62	.77		.40	.85	1.12	.71	1.00	1.00	.35	1.11
	R	.69	.57	.38		.18	.66	.23	0	.45	.28		.80	.22	.13	.39	.35	.00	.44	.26
1/75	D	1.76	1.82	1.58		2.35	1.06	1.27	1.76		2.24					2.24				
	E	.66	.55	.57		.70	.66	.50	1.00		.85					.70				
	R	.32	.46	.46		.32	.42	.61	.10		.25					.35				
3/75	D	1.75	1.77	1.65		2.24	2.08	1.16	1.49	2.34	2.77		.56	1.39	.50	1.64	.64	.50	1.84	2.21
	E	.57	.40	.50		150	.75	.60	1.00	.63	1.00		.66	.60	.33	.80	.33	.40	.50	.85
	R	.44	.53	.53		.42	.34	.56	.26	.37	0		.56	.43	.84	.32	.86	.85	.46	.26
5/75	D	1.62	2.05	2.00		1.65	2.80	1.44	.97	2.52	1.27	.96	1.48	1.64	2.63	1.46	1.39	1.41		2.10
	E	.57	.55	.62		.44	.66	.20	.50	.80	.23	.71	.40	.27	.18	.23	.50	.50		.56
	R	.57	.38	.46		.49	.31	.61	.58	.40	.68	.68	.49	.58	.29	.64	.64	.31		41
7/75	D	1.74	1.76	2.01		1.76	1.61	1.18	.86	2.78	2.59	1.96	.68	1.12	1.06	1.26	1.23	.78	2.14	.64
	E	.57	.44			.36	.36	.75	.33	.86	.50	.71	.66	.27	.22	.33	.50	.50	1.00	.40
		.34	.45	.41		.51	.56	.41	.75	.22	.39	.39	.64	.72	.70	.66	.61	.65	.27	.83
9/75	D	2.31	2.40	1.96		2.18	1.55	1.33	1.52	1.82	1.43	1.81	.50	2.34	1.18	2.38	1.57	.54	2.22	1.74
	E	.58	.63	.62		.66	.44	.50	.80	.62	.37	.33	.33	.46	.42	.63	.44	.25	.57	.40
	R	.43	.33	.36		.35	.61	.56	.37	.41	.62	.65	.84	.45	.71	.39	.52	.88	.47	.50
11/75	D	1.16	1.10	2.86		2.65	.84	.70	.35	2.29	2.20	1.90	.40	2.48	2.28	2.35	.95	2.26		2.12
	E	.27	.42	.90		1.00	.40	.40	.33	.70	.85	.45	.25	.88	1.00	1.00	.25	1.00		.75
	R	.73	.73	.13		.16	.79	.79	.89	.34	.28	.50	.84	.20	.22	.16	.73	.07		.52
1/76	D	2.18	.55	2.81		3.32	2.41			2.63	1.63		1.96	2.90	1.44	1.84	1.33	.57		
	E	.40	.14	.66		.70	1.00			.64	.30		.55	.90	.42	.55	.23	.40		
	R	.49	.89	.27		.26	.21			.39	.59		.41	.16	.71	.60	.87	.77		
3/76	D	2.94	1.51	2.17		2.67	1.41	.90	1.44	2.83	.51		2.19	3.07	.47	2.53	1.84	1.02	2.19	2.16
	E	.78	.50	.50		.50	.50	.50	.60	1.11	.66		.54	1.26	.40	.88	.55	.40	.87	.75
	R	.21	.57	.44		.44	.51	.69	.40	0	.83		.42	.20	.90	.27	.47	.65	.27	.29
5/76	D	2.49	2.23	2.39		2.73	1.63	2.39	1.26	2.10	3.24	2.23		2.19	2.16	1.95	1.93	1.14	1.57	2.01
	E	.61	.60	.70		.81	.80	.63	.50	.66	.77	.75		.66	.66	.55	.55	.60	.66	.50
	R	.37	.41	.29		.25	.48	.45	.61	.35	.37	.21		.34	.39	.43	.44	.58	.45	.45
7/76	D	2.55	2.18	2.64		2.35	2.75	1.84	.58	1.53	2.17			1.01	2.50	1.88	.71	1.58	2.65	2.00
	E	.44	.85	.60		.58	.56	.38	.40	.30	.60			.16	.88	.38	.16	.50	.60	.50
	R	.40	.35	.38		.40	.37	.56	.78	.67	.37			.75	.19	.54	.81	.50	.35	.42

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[1] Harrel and Duplechin (1976); Lloyd and Ghelardi (1964)

clean water or recovered streams and streams receiving pollution. At most clean water streams, the values ranged between three and four. In polluted streams the diversity values were altered. In most cases the diversity values were less than one.

In Piceance Creek, diversity values ranged from 0.35 to 3.32. Most values were 2.0 or below. This would indicate that Piceance Creek could not be considered a clean water stream and at times would be considered polluted.

In Stewart Creek, diversity values ranged from 0.51 to 3.24. The majority of the time diversity values were between two and three. This indicates that Stewart Creek could not be considered a clean water or polluted stream, but falls somewhere in between, and is of better quality than Piceance Creek.

In Willow Creek, diversity values ranged from 0.47 to 3.15. Most of the time values were between two and three, indicating that Willow Creek is similar to Stewart Creek.

In the White River, diversity values ranged from 0.64 to 2.88. Most of the time values were between two and three, indicating some degradation of the river with respect to a clean water stream.

Lloyd and Ghelardi (1964) discussed the "Equibility" component of species diversity. They postulate that whereas the number of species depends on the structural diversity of the habitat, "equibility" is more sensitive to the stability of physical conditions. With these assumptions, "equibility" could provide a means of determining if a low diversity index were due to poor habitat or degradation of physical conditions. MacArthur's model (Lloyd and Ghelardi 1964) is used to examine the number of species found in the samples versus the theoretical number that would occur among a community that conforms to the model. Thus a ratio is obtained to equate the species observed with its potential maximum. Under these conditions an equibility value of 0.60 would mean that due to inequibility in the distribution of individuals among the species collected, the sampled community has a diversity appropriate to a community of only 60 percent as many species as actually occur (Lloyd and Ghelardi 1964). Weber (1973) found equibility values greater than 0.5 were indicative of clean water streams, whereas polluted areas were between 0.0 and 0.3. Equibility values for Piceance Creek stations varied from 0.14 to 1.07, but generally averaged about 0.57. In Stewart Creek, values ranged from 0.23 to 1.11, and averaged about 0.66. In Willow Creek, values ranged from 0.16 to 1.26 and averaged about 0.60. In the White River, values ranged from 0.33 to 1.11 and averaged about 0.62 (Table 3-5-4). This seems to indicate no degradation of these streams due to physical conditions during most of the year. The validity of species diversity and its components has been disputed by various workers.

Redundancy values were computed for all stations (Table 3-5-4) to calculate dispersion values in an effort to detect areas (stations) along the stream which were degraded compared with upstream or downstream stations. Because of the small number of stations of Stewart and Willow Creeks and the White River, only Piceance Creek was examined in this manner. The analyses indicate that there are portions of Piceance Creek within the study area that are degraded relative to the surrounding region. These areas are not consistent throughout the year, but fluctuate seasonally. However, generally speaking, the portions of Piceance Creek in the vicinity of Stations P-2, P-3, P-5A, P-6, and P-7 show degraded conditions during certain times of the year.

Studies conducted by Everhart and May (1973), May (1970), and Woodling and Kendall (1974) on benthic invertebrates in Piceance Creek and Stewart and Willow Creeks identified similar benthic macroinvertebrate populations at stations which corresponded with those in this study. Allan (1975) and MacKay and Kalff (1969) found there was a direct effect upon numbers and diversity of benthic invertebrate populations due to the substrate complexity. This was also found in this study. Stations P-6 and P-7 which had the poorest substrate (clay and mud, with some small gravel) had the poorest benthic invertebrate communities.

3.5.5.5 Fish Populations

Three species of trout and various non-game fish occur in the vicinity of Tract C-b. Brook trout (Salvelinus fontinalis), rainbow trout (Salmo gairdneri) and brown trout (Salmo trutta) were captured during the study. However, rainbow and brown trout are relatively rare in the Tract vicinity. Other fish include the mountain sucker (Catostomus platyrhynchus), speckled dace (Rhinchythys osculus), mottled sculpin (Cottus bairdi) and flannelmouth sucker (Catostomus latipinnus) (Appendix IV-B, Table B-5-8).

In the vicinity of the Tract, Piceance Creek supports higher populations of fish than are found in Stewart or Willow Creeks. These are primarily mountain sucker, brook trout, and speckled dace. A few rainbow and brown trout have been collected in Piceance Creek. Stewart and Willow Creeks support some brook trout, mountain suckers, and speckled dace. Lower Stewart Lake and its drainage channel, which empties into Stewart Creek, support a fair size population of brook trout. The three other lakes studied contain no fish.

The White River at its confluence with Piceance Creek has a river environment compared to the small-stream environment of Piceance Creek. However, cold water fish species are more abundant upstream near headwater regions of the White River than in the vicinity of Piceance Creek. Mottled sculpin are abundant in the White River. In addition, mountain whitefish, flannelmouth suckers, and speckled dace have been collected. Sampling in the White River is difficult and data obtained on fish species of the White River is sketchy compared to the other areas under study.

All fish captured during the baseline study are listed by station and sampling period in Appendix IV-B (Table B-5-9).

3.5.5.5.1 Mountain Sucker

The mountain sucker was the most abundant species in the collections made during the baseline study. They were captured throughout Piceance Creek, and were also taken on occasion in Stewart and Willow Creeks (Appendix IV-B, Table B-5-9). The Piceance Basin is reported to be the only known area of occurrence of the mountain sucker in Colorado (R. Behnke pers. comm., Smith 1966). They are very similar in appearance to the bluehead sucker (*Catostomus discobolus*) which has a more widespread distribution in Colorado.

Length-frequency data were compiled for mountain suckers captured during the study (Appendix IV-B, Table B-5-10). Data on length-frequency distributions were also graphed for each sample (Appendix IV-B, Figure B-5-15). Mountain suckers were aged by scale readings. Data on age group versus length were compiled (Table 3-5-5). Fish captured ranged in age from 0+ to 4+ (Ricker 1968a). The size ranges for a given age fish collected in this study were greater than those reported by Hauser (1969).

Mountain suckers spawn in spring and early summer in Piceance Creek. This is consistent with spawning habits reported for the mountain sucker by Smith (1966), Hauser (1969), Sigler and Miller (1963), and Baxter and Simon (1970). Newly hatched fish were collected in July along with spawning fish in 1975. In 1976 spawning appeared to be earlier than the previous year. Flow rates and turbidity were reduced in the spring of 1976 as compared to 1975. Male fish developed reddish bands on their sides and turberculate caudal and anal fins during spawning. Females also showed some coloration. Fecundity studies on female fish indicated both developing and recruitment eggs as reported by Hauser (1969). Recruitment eggs were carried year-round and developed for the spring spawning period. No fish were taken with empty (spent) ovaries except for immature fish. All other female fish contained eggs at some stage of development throughout the year. Fish contained approximately equal numbers of developing and recruitment eggs. Fecundity estimates for fish ranging in length from 117 to 190 mm total length ranged from approximately 2,538 to 13,996 total eggs (Appendix IV-B, Table B-5-11). These estimates included developing and recruitment eggs. Estimates for developing eggs only would range from approximately 1,269 to 6,998 eggs. This is a more accurate estimate of the number actually spawned per breeding season. Analysis of reproductive condition in mountain suckers in Piceance Creek indicates most fish are mature and able to spawn at 100 mm total length. The smallest mature fish captured was 70 mm total length. All fish less than 70 mm total length were immature. These sizes are smaller than those found for

Table 3-5-5 LENGTH-AGE RELATIONSHIP OF MOUNTAIN SUCKERS CAPTURED AT PICEANCE BASIN STATIONS, AUGUST 1974 - JULY 1976

	Age[1] (years)[2]				
Length (mm)	0+	1+	2+	3+	4+
50	1				
60					
70					
80	2				
90	4	4			
100	1	5			
110	3	4	1	1	
120		6	6	4	
130		3	10	3	
140		3	11	8	
150			7	19	
160			2	9	2
170			4	1	
180			4	1	2
190				2	2
200				1	
210				1	
TOTALS	11	25	45	50	6
AVERAGE LENGTH	90-100	110-120	140-150	150-160	170-180

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[1] Ages determined by scale readings.
[2] Based on Ricker (1968).

immature mountain sucker by Hauser (1969) in Montana.

Length-weight relationships were plotted for each year and linear regression lines fitted to the data for mountain suckers to examine growth rates (Figures 3-5-14 and 3-5-15). Two growth stanzas were arbitrarily selected based on visual inspection as discussed by Ricker (1968a). Mature fish increased in weight relative to length at a faster rate than immature fish. Data were compiled for two periods (September 1974-November 1975, November 1975-July 1976). Computed growth rates varied somewhat between the two years (Figures 3-5-14 and 3-5-15). Growth rates were also examined utilizing fish ages, determined by scale readings, and average length and weight (Figure 3-5-16). Average growth (in length) was determined to be 17.6 grams (Figure 3-5-16). However, data indicate that increases in length and weight are not a linear relationship. The rate of increase in length diminshed in older fish, whereas the rate of increase in weight is greater in older fish.

Condition factors were computed for mountain suckers of selected size ranges (assuming allometric growth) for the various months during the study period (Appendix IV-B, Table B-5-12). Values did not fluctuate greatly during the year. They appeared to be in similar condition year round.

Stomach contents of selected mountain suckers were examined to determine feeding habits. Algal material comprised the major portion of the diet along with some dipteran and ephemeropteran insects (Appendix IV-B, Table B-5-13).

Scale aging of mountain suckers has determined fish from age groups 0+ to 4+ comprise the majority of the mountain sucker population in the Piceance Basin. The mountain sucker population in Piceance Creek appears to be well established and thriving. Estimates of abundance of mountain sucker range as high as 101 fish per 100 meter stretch of stream in Piceance Creek.

3.5.5.5.2 Speckled Dace

Speckled dace were frequently collected along with mountain suckers. Spawning occurred in late spring and summer. Male speckled dace developed reddish fins and red coloration on the lower jaw during the spawning period. Ovaries contained developing eggs as well as recruitment eggs. Fecundity estimates for female fish 87 to 119 mm in total length ranged from approximately 2,700 to 7,000 eggs (Appendix IV-B, Table B-5-14). Estimates of speckled dace abundance ranged as high as 115 fish per 100 meter stretch of stream. Abundance varied in the vicinity of the Tract, depending on station location. Speckled dace were also collected from the White River in addition to Piceance, Stewart, and Willow Creeks.

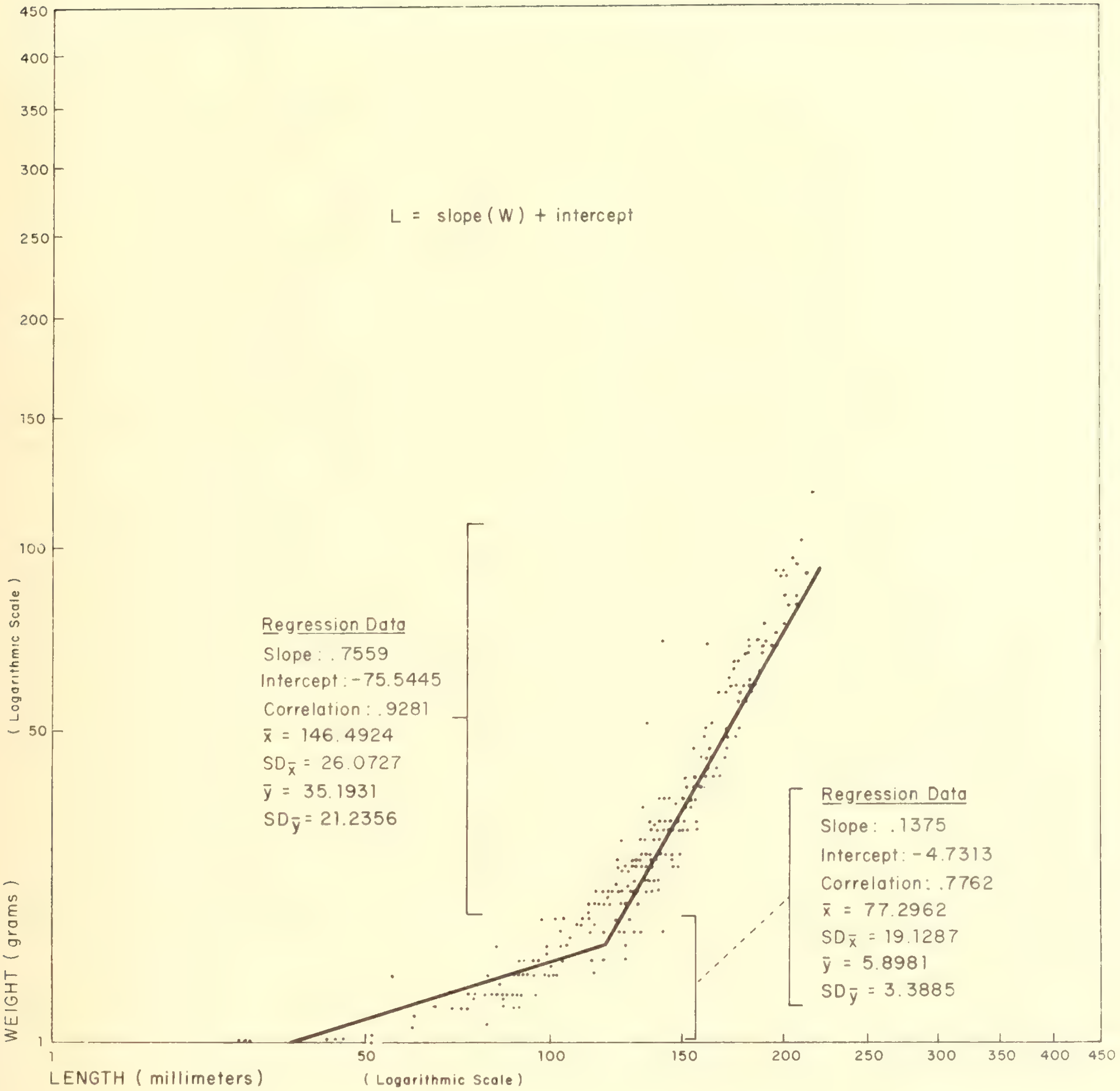

Figure 3-5-14
LENGTH-WEIGHT LINEAR REGRESSION FOR MOUNTAIN SUCKERS
FROM PICEANCE BASIN (two growth stanzas computed)
SEPTEMBER 1974 - NOVEMBER 1975

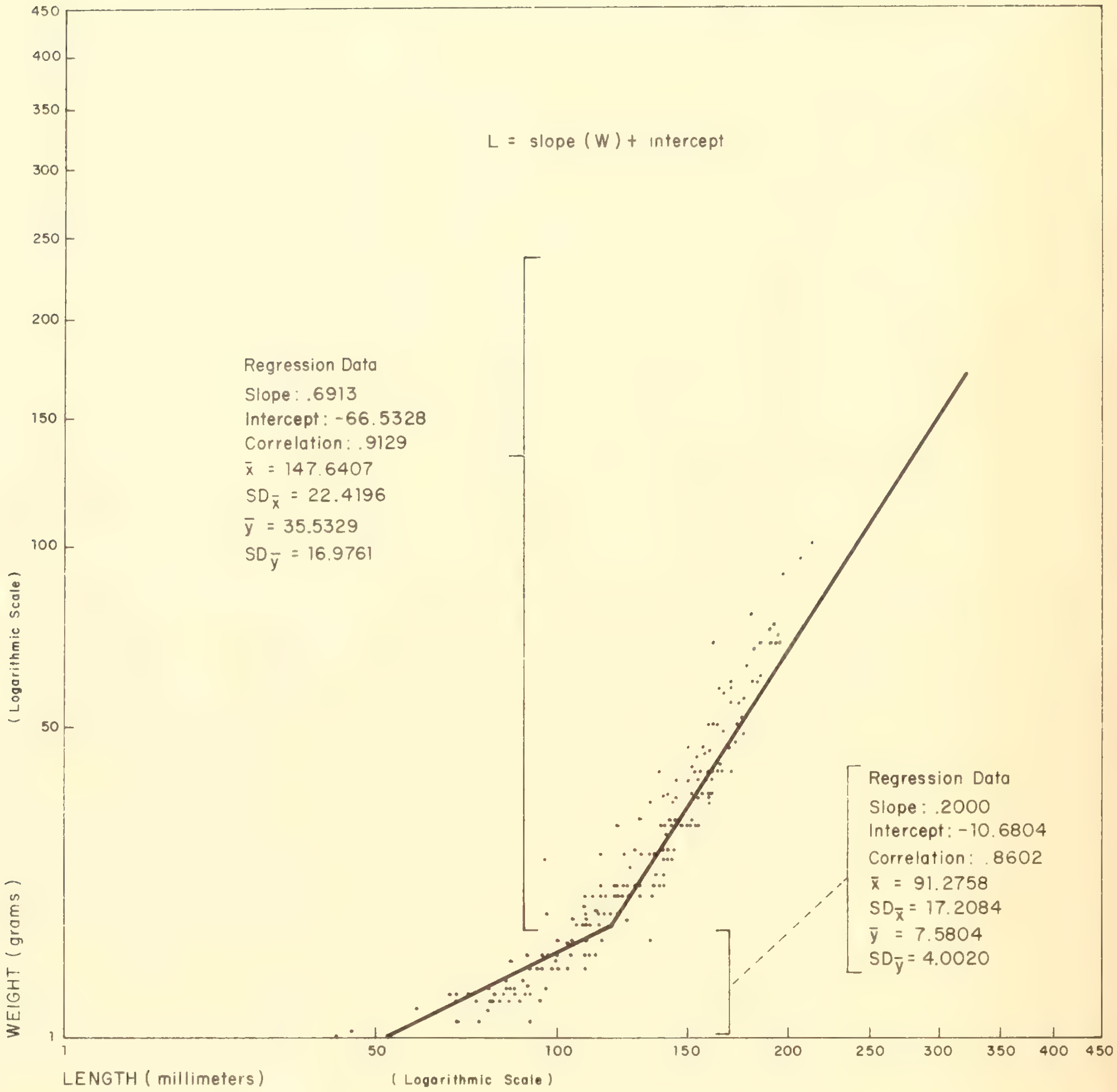

Figure 3-5-15
LENGTH-WEIGHT LINEAR REGRESSION FOR MOUNTAIN SUCKERS FROM PICEANCE BASIN (two growth stanzas computed) NOVEMBER 1975 - JULY 1976.

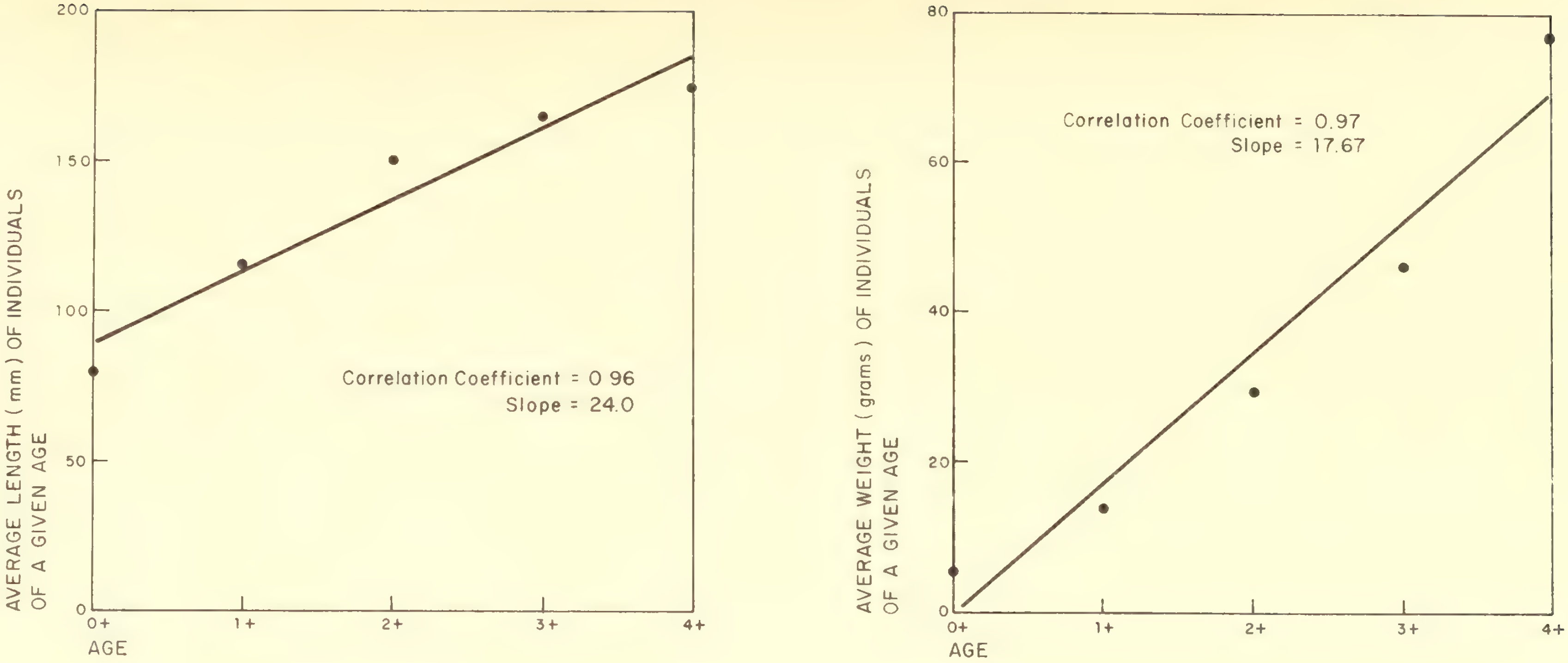

Figure 3-5-16
MOUNTAIN SUCKER GROWTH RATES DETERMINED FROM FISH AGED BY SCALE READINGS USING AVERAGE LENGTH (A) AND WEIGHT (B).

3.5.5.5.3 Brook Trout

Brook trout are the predominant trout species in the Tract vicinity. A few rainbow and brown trout were collected. Brook trout occur in Stewart Creek, Lower Stewart Lake, Willow Creek, and Piceance Creek. Suitable habitat varies along Piceance Creek and fish abundance reflects habitat suitability.

Length-frequency data were compiled for brook trout captured during the study (Appendix IV-B, Table B-5-15). Length-frequency data were also graphed for the monthly samples (Appendix IV-B, Figures B-5-16 to B-5-20). Brook trout were aged by scale readings. Data on age group versus length were compiled (Table 3-5-6). Fish captured ranged in age from 0+ to 4+. It is reported that brook trout seldom live beyond five years of age in the wild and never beyond eight years (Scott and Crossman 1973). Length-frequency data indicated three to five age groups were collected at various times (Appendix IV-B). The largest individuals collected were taken in fall during the spawning period indicating there may be a spawning migration into the study area of larger fish in the fall. Young fingerling brook trout were collected during the spring in Stewart Creek and Lower Stewart Lake indicating that successful spawning occurs in these areas. Spawning brook trout were captured in Piceance Creek in the fall below a barrier to upstream migration (waterfall at Station P-5A). Spawning took place primarily in October and early November in the Tract vicinity. It seems likely that spawning fish below the barrier at Station P-5A may have migrated upstream from the White River to spawn. Egg diameters from one spawning female captured and released in November ranged from 4.0 to 5.0 mm. Similar egg sizes are reported for brook trout by Scott and Crossman (1973). Fecundity estimates were made for several female brook trout (Appendix IV-B, Table B-5-16). Estimates for fish 225 to 297 mm total length ranged from 978 to 2,155 eggs produced. These estimates agree with the findings of other workers (Scott and Crossman 1973, Vladykov 1956).

Stomach contents of selected fish were examined to determine feeding habits (Appendix IV-B, Table B-5-17). Those examined had fed primarily on aquatic invertebrates. Dipterans were eaten in the greatest numbers. Annelids, crustaceans, plecopterans, ephemeropterans, hemipterans, trichopterans, coleopterans, homopterans, and some algal material were also consumed. Griffith (1974), Wurtsbaugh et al. (1975), Miller (1974), and Leonard (1941) reported similar feeding habits for brook trout. Reed and Bear (1966) found brook trout consumed more terrestrial insects than aquatic invertebrates. In this study, terrestrial insects formed an insignificant amount of the total diet.

Estimates of brook trout abundance range as high as 14 fish per 100 meter stretch of Piceance Creek. Abundance varies between stations. At some stations, brook trout were never taken during the two-year baseline study. Lower Stewart Lake supports a population

Table 3-5-6 LENGTH-AGE RELATIONSHIP OF BROOK TROUT CAPTURED AT PICEANCE BASIN STATIONS, AUGUST 1974 - JULY 1976

	Age[1] (years)[2]				
Length (mm)	0+	1+	2+	3+	4+
90	1				
100	3				
110	9				
120	7				
130	7	2			
140	5	3			
150	2	2			
160					
170	1				
180		1			
190		1	1		
200		2			
210	1	1			
220		1			
230		3			
240		1			1
250		3			
260		2			
270		3			
280		1			
290		2			
300			1		
310		1			
320			3		
330					
340			1	3	
350					
360					
370					
380					
390					2
Totals	36	29	6	3	3
Average Length (mm)	120-130	220-230	300-310	340-350	340-350

[1] Ages determined by scale readings.
[2] Based on Ricker (1968).

of approximately 100 brook trout.

Length-weight relationships were plotted for each year and linear regression lines fitted to the data to examine brook trout growth (Figures 3-5-17, 3-5-18). Two growth stanzas were arbitrarily selected based on visual inspection as discussed by Ricker (1968a). Older fish showed a greater increase in weight relative to length than young fish. Data were compiled for two periods (September 1974-November 1975; November 1975-July 1976). Rates were similar for the two periods. Growth rates were also examined utilizing fish ages determined by scale readings, and average length and weight (Figure 3-5-19). The average increase in length was determined to be 60 mm per year (Figure 3-5-19). The average increase in weight was determined to be 117 gm per year. However, data indicate that weight increase is not a linear relationship. There is an increase in younger fish with a leveling off among older fish (Figure 3-5-19). Brook trout growth rates are reported to vary widely, depending on the type of habitat (Scott and Crossman 1973).

Growth rates were examined utilizing tag-recapture data for brook trout and mountain suckers. Tag-recapture growth data must be examined in light of numerous workers' findings of slowed growth in tagged versus untagged fish (DeRoche 1963, Ricker 1962) and varying growth rates seasonally. Growth of the 22 recaptured brook trout varied from -9 to 61 mm (Appendix IV-B, Table B-5-18). Some of these fish were only at large for a two-month period. Others were at large for up to 10 months. Overall, the growth rate of tagged fish was comparable to that computed from length-weight and length-age data. Some fish showed a negative growth in the first few months after tagging. Some exhibited growth rates of up to 53 mm in a six-month period. If expanded to a year's period, this rate would be approximately double that computed from the methods mentioned above. However, rates are probably reduced in winter. The highest rates were found in summer and fall (Appendix IV-B, Table B-5-18). The ten month rate (61 mm) is very similar to the rate computed from length-age data (60 mm/year).

Condition factors were computed for brook trout of selected size ranges (assuming allometric growth) for the various months. Fish were in the best condition during late summer and fall prior to spawning, with the poorest condition occurring in winter after spawning, with an improving trend in spring (Appendix IV-B, Table B-5-19).

Fish were tagged and released during the study in an effort to study migration patterns, examine growth, and estimate the population size. During the study, 149 brook trout were tagged and released. Twenty-two brook trout were recaptured (Appendix IV-B, Table B-5-20). All recovered fish were recaptured at the same stations at which they were originally tagged, indicating little, if any, migration among brook trout in the Tract vicinity. However, as previously discussed, it appears some spawning fish migrate into the area from downstream

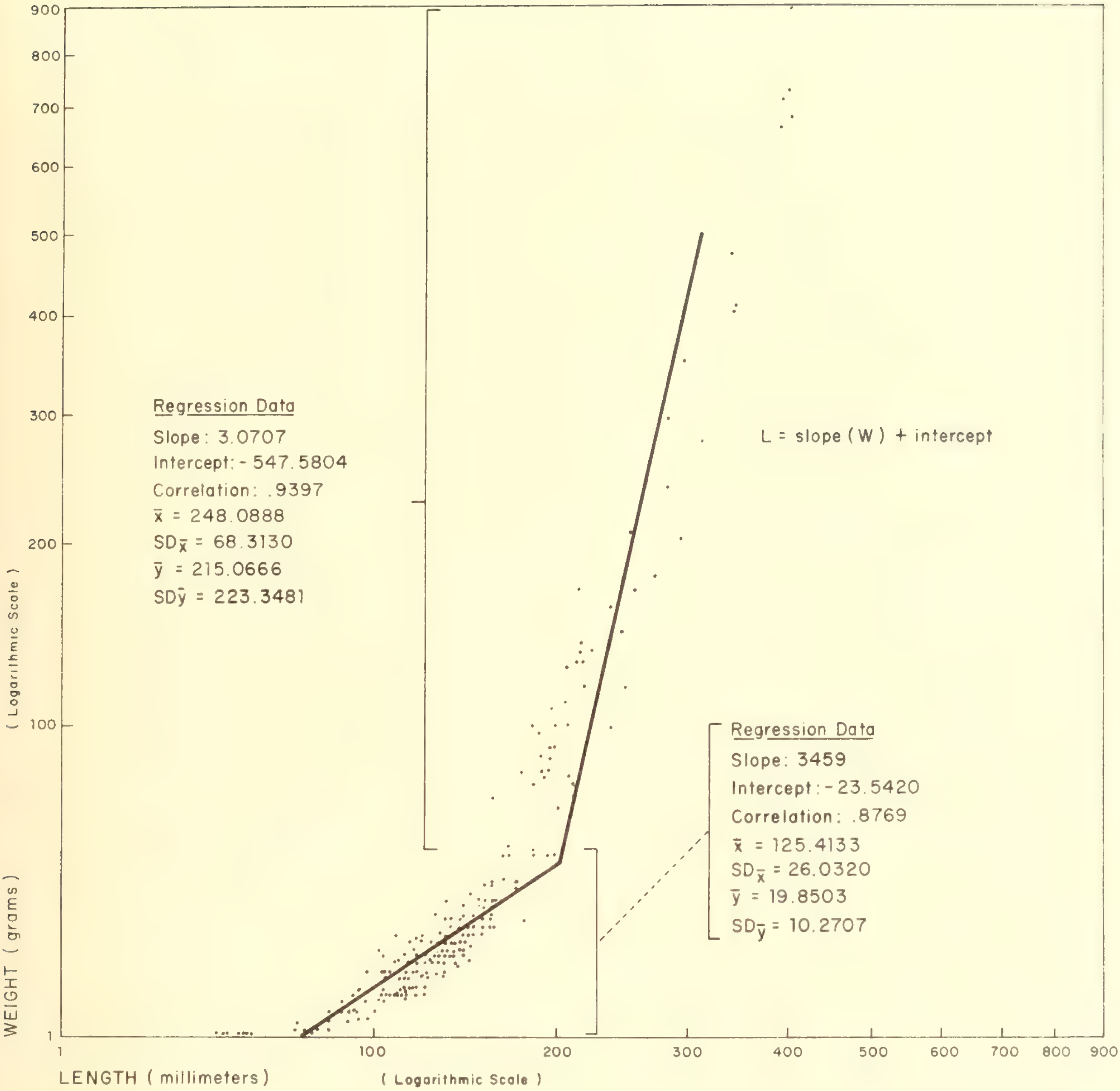

Figure 3-5-17
LENGTH-WEIGHT LINEAR REGRESSION FOR BROOK TROUT FROM PICEANCE BASIN (two growth stanzas computed)
SEPTEMBER 1974 - NOVEMBER 1975

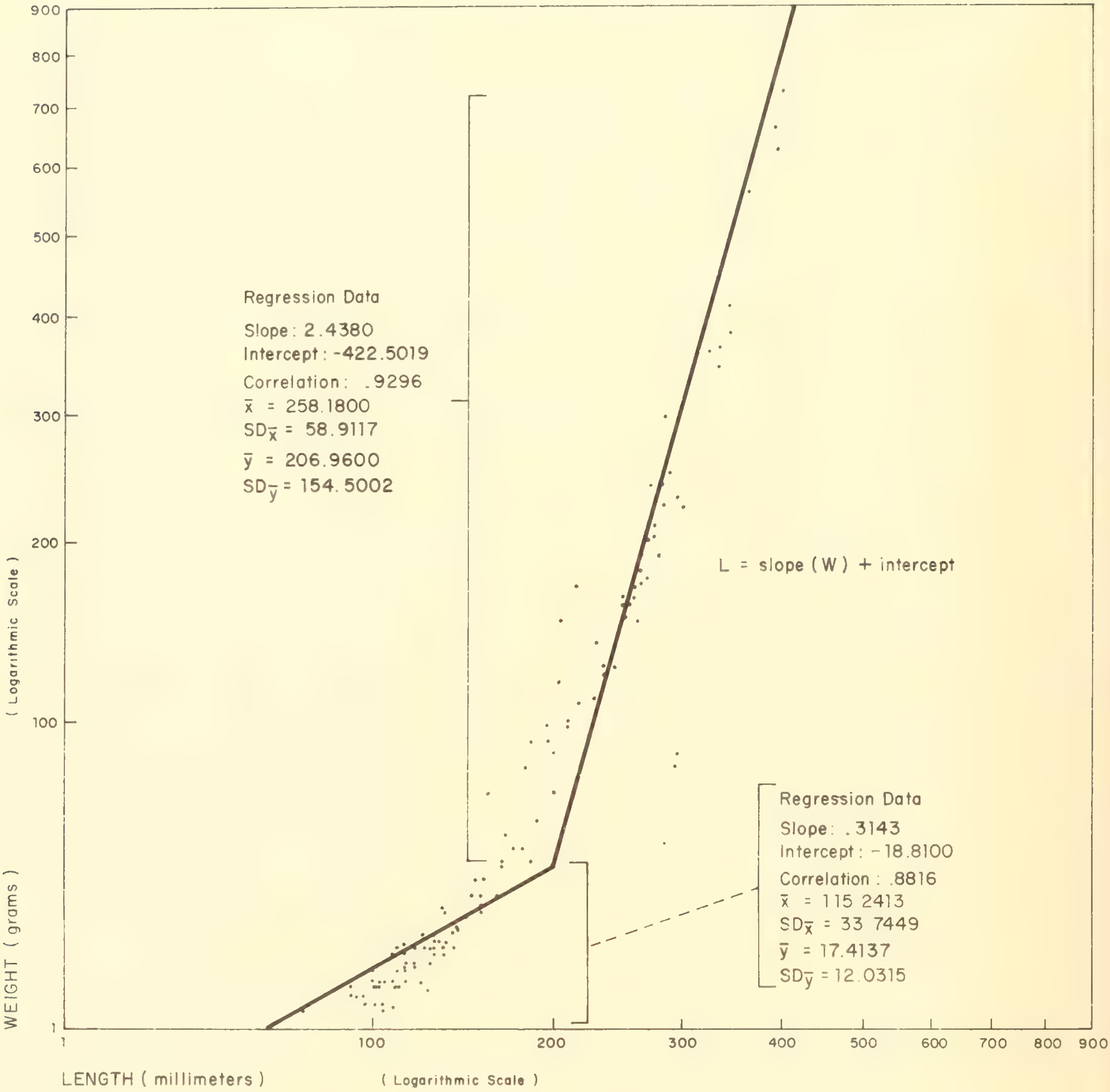

Figure 3-5-18
LENGTH-WEIGHT LINEAR REGRESSION FOR BROOK TROUT FROM PICEANCE BASIN (two growth stanzas computed) NOVEMBER 1975-JULY 1976

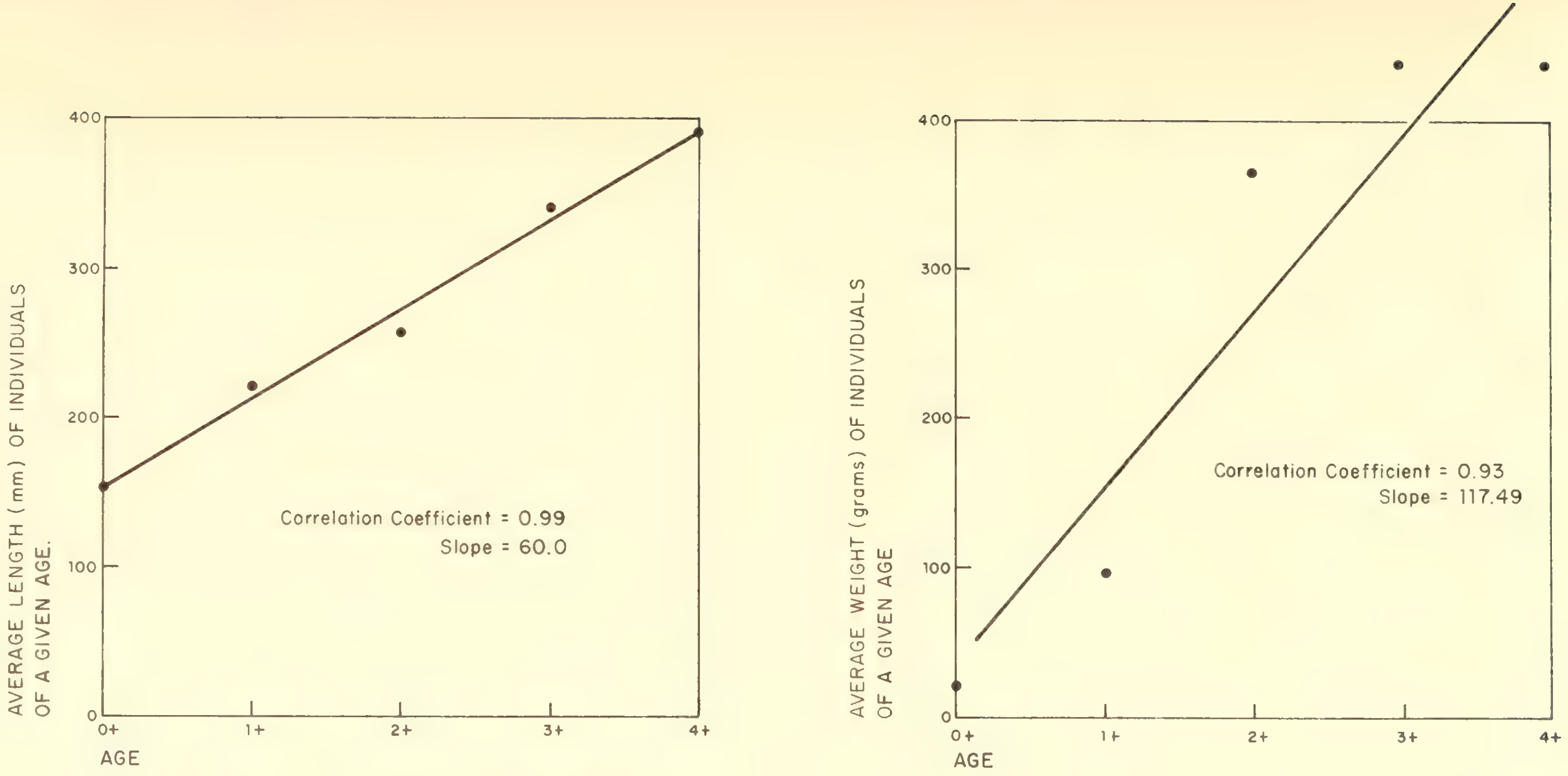

Figure 3-5-19
BROOK TROUT GROWTH RATES DETERMINED FROM FISH AGED BY SCALE READINGS USING AVERAGE LENGTH (A) AND WEIGHT (B).

in the fall, and then leave again after spawning. It is also possible that some tagged fish migrate out of the sampling area and do not return.

No endo- or ectoparasites were detected from fish collected. Some fish did show indications of eroded fins and in one case lacerations. The fungus Saprolegnia parasitica had invaded the wound, probably as a secondary invader.

3.5.5.5.4 Other Fish Species

In addition to the three most abundant species discussed above, which comprised most of the catch, five other species were collected during the study.

Rainbow trout were captured in Piceance Creek on occasion. Several of the farm ponds along Piceance Creek have been stocked with rainbow trout. It is very likely that the captured rainbows entered Piceance Creek from one of these ponds.

Two brown trout were captured in Piceance Creek during the study.

In the White River, mottled sculpin, mountain whitefish and flannelmouth sucker were collected. Mountain whitefish were abundant in the White River in spring. Mottled sculpins were also abundant in the White River.

Fish population estimates were made using the Delury method (Delury 1947) with Zippin's (1958) formulae (Appendix IV-B, Tables B-5-21 to B-5-24). An estimate of the brook trout population in the study area was made using Chapman's formula (Ricker 1968b) for mark-recapture estimates (Appendix IV-B, Table B-5-25). The fish population varies between stations. Estimates based on the Delury estimate ranged from 39 to 131 fish per 100 meter stretch of stream. The 95 percent confidence interval placed on these estimates was 24 to 47 fish for the 39 fish/100 meter estimate and 43 to 218 for the 131 fish/100 meter estimate (Appendix IV-B, Tables B-5-21 to B-5-24). The estimated brook trout population in the study area based on mark-recapture data was 626 fish. The 95 percent confidence interval for this estimate was 449 to 1031 fish (Appendix IV-B, Table B-5-25).

Stations were compared with regard to fish species using Sorensen's Index of similarity (Krebs 1972, Cox 1972, Greig-Smith 1964). Values range from 1 - if all the species are common to both samples, to 0 - if none of the species is common to both samples. Because there is no statistical significance level attached to the index, an arbitrary similarity value (0.65) is selected above which the two samples are considered similar, and below which they are considered dissimilar. The similarity of species composition between stations was computed for the four streams studied (Appendix IV-B, Tables B-5-26 to B-5-29). On Piceance Creek, Stations P-1, P-2, and P-3 appeared to be similar. Other stations were dissimilar. Stations P-6 and P-7 were markedly different that the upstream stations (Appendix IV-B, Table B-5-26). Stewart Creek Stations were dissimilar. Stations S-2 and LSL (Lower Stewart Lake) were similar (Appendix IV-B, Table B-5-27). Fish were rarely taken in Willow Creek except at station W-3. The two White River stations were dissimilar (Appendix IV-B, Table B-5-29). White River fish species could not be adequately sampled due to physical characteristics of the river.

Friedman's nonparametric analysis (Zar 1974) was used to test the null hypotheses that there was no difference between stations sampled with regard to fish species distribution. The hypothesis was rejected for all streams studied except the White River (Appendix IV-B, Table B-5-30). Multiple comparisons were made with the conclusion that Stations P-1, P-2, and P-3 were similar to one another but different from P-5, P-6, and P-7, which were also similar (Appendix IV-B, Table B-5-30). On Willow Creek Station W-3 was determined to be different from W-1 and W-2 (Appendix IV-B, Table B-5-30). Stewart Creek Station S-2 was determined to be similar to Lower Stewart Lake (LSL) but different from Station S-1 (Appendix IV-B, Table B-5-30).

3.5.5.6 Springs and Seeps

Data collected in the springs and seeps studies are presented in Appendix IV-B. Sampling was conducted in March, July, and November 1975 and March and July 1976. Invertebrates collected from springs and seeps were also found at the aquatic sampling stations with few exceptions (Appendix IV-B, Tables B-5-31 to B-5-34). Water quality parameters measured were similar to those found at aquatic stations. Most springs had higher flow rates in November 1975 than during the other sampling periods. However, Spring 8 along Willow Creek was dry for the first few meters below its original source and had a diminished flow compared to the March and July 1975 sampling periods.

Species collected from the springs and seeps that were not collected at aquatic stations included: Polycelis, Agraylea, and Dicranota. In November 1975, invertebrates were collected from a spring known to be extremely high in dissolved salts located near the mouth of Piceance Creek (Appendix IV-B, Table B-5-32). Invertebrates collected at this spring belong to families that have been collected at the aquatic stations.

3.5.5.7 Other Studies

Other researchers have conducted studies at some of the same stations or at similar stations as were used in this study. These have been detailed in this report under the descriptions in the Methods section (Appendix IV-B, Table B-5-35).

Everhart and May (1973) and May (1970), which both report on the same study, conducted studies on water quality, benthic invertebrates and fish. They reported similar results to our findings for water quality and benthos at our Stations P-1, P-5A, and P-7. Water temperatures were higher in summer during their study. Their results for the White River station (WR-1) showed higher water temperatures in summer, lower conductivity and dissolved oxygen readings, but similar pH and benthos findings.

They reported five species of fish from Piceance Creek: Bonytail chub (*Gila elegans*), black bullhead (*Ictalurus melas*), red shiner (*Notropis lutrensis*), mountain whitefish (*Prosopium williamsoni*), and the mottled sculpin (*Cottus bairdi*) which have not been taken in Piceance Creek during this study. The mottled sculpin and mountain whitefish have been collected at our White River stations.

Pettus (1974) reports the mountain sucker from Piceance Creek. His sampling at our White River station (WR-2) yielded the bluehead sucker (*Castostomus discolobus*) and the white sucker (*Catostomus commersoni*) which have not been collected in this study.

Pennak (1974) found similar water quality results for Stations WR-1 and WR-2 examined in this study.

Woodling and Kendall (1974) found similar results for water quality and benthos at Stations P-2, P-6, S-1, and W-3 examined in this study. They report the bluehead sucker from Piceance Creek. This species is very similar to the mountain sucker collected in our studies and may have been identified incorrectly by Woodling and Kendall.

Studies have been conducted jointly in Piceance Basin by the Natural Resource Ecology Laboratory at Colorado State University and the Fisheries Bioassay Laboratory at Montana State University (Thurston et al. 1975, 1976). These studies have dealt with fish and macroinvertebrate distribution, water chemistry, and some laboratory studies on effects of mining operations on aquatic biota. Goettl and Edde (in Thurston et al. 1976) report the same fish species for Piceance Creek that have been collected in our study. Results of aquatic macroinvertebrate studies have been similar to findings during this study, as have water quality parameters.

3.6 Threatened, Endangered, and Unusual Species

Legally designated threatened, endangered, and fully protected or otherwise unique and unusual species known to occur in the Piceance Basin are discussed in Volume I of this report series. No species, included in the legally designated threatened and endangered categories, were found to nest or to be permanent or seasonal residents within the C-b study boundaries during the two-year baseline studies, nor were any unique species or habitats observed. Therefore it is unlikely that development activities on the C-b Shale Oil Lease Tract will significantly impact species considered to be threatened, endangered, or unusual.

This section provides a discussion of the possible future uses of the data and analyses resulting from the Tract C-b baseline studies. The discussion is based on the Principle Investigators' opinions on the potential utility of their baseline studies to the operator, regulatory agencies, and other interested parties for monitoring the effects of shale oil development. The parameters studied during the baseline that will be of value when monitored on a continuing basis and those which can be monitored on a discontinuous basis or deleted from the continuing program are identified. These discussions are restricted to those parameters already considered as integral parts of the baseline and therefore do not include discussions of a variety of other parameters (including plant and animal physiological and histological parameters) which have been discussed in the DDP and in the interim and long-term monitoring plans.

In order to maintain continuity in, and the comparative validity of, the baseline and monitoring data through time, the monitoring programs should be instituted as soon as possible and continued throughout the life of the project, including the reclamation period. Biological parameters have natural variabilities, therefore a greater amount of data available over the predevelopment period will provide a better understanding of these inherent variations. These data collected through time will allow a more accurate definition of general or "normal" trends and anomalous accuracies that may be attributable to shale oil development. If the sampling programs, as recommended in this section and those included in the monitoring plan, are not conducted from 1977 through project completion, natural short-term variations (apparent reductions and increases, both beneficial or detrimental) in the various parameters may be attributed to shale oil development, when in fact they are within the normal range of variability. Without continuous monitoring to provide a link between the two year baseline and the construction and operational phases, a natural long-term trend could also appear as a distinct shift in the level of a certain parameter and be attributed to shale oil development. In addition, the acquisition of continuous data through time is necessary for production of baseline data on physiological and histological parameters. Such parameters will provide the most rapid responses to detrimental effluents and emissions.

A general consideration in making the following comments and recommendations is the future application of these studies to both natural trends in the system and to development induced perturbations. As such, the approach taken to making recommendations was made broad enough to include so-called system-dependent studies that would enter into the monitoring program scope as appropriate, as well as including continuous monitoring studies. As an additional general recommendation it is suggested that the majority of monitoring is of major importance since these factors concentrate on the lower trophic levels at which perturbations are detected earliest and most easily.

4.1 Microenvironment

Measurement of the abiotic microenvironmental components of the ecosystem have a significant influence on the growth and productivity of plants, and on the activity and survival of animal species.

Analysis of microenvironmental data gathered during the baseline studies has determined statistically significant differences at a 90 percent level of confidence between the microclimates of the major vegetation types and between years of the baseline period. Microenvironmental differences between major vegetation types are shown to be directly correlative to the structure of the vegetation in these types. This feature of the vegetation in turn has a significant influence on the water balance in each vegetation type. Microenvironmental parameters measured during the baseline period that give useful information relative to site differences are soil, surface, and air temperatures; soil moisture; precipitation; potential evaporation; and wind speed. With the exception of wind speed, these data have been used in correlating plant productivity between sites and between years of the baseline. The majority of the parameters will have continued utility in comparing the predevelopment and operational periods of shale oil development. Baseline data, in conjunction with monitoring data, can also provide comparisons of soil water regimes and plant/soil relationships between natural variations and development-induced changes.

Several of the parameters measured during the baseline are not recommended for inclusion into the monitoring programs. Included in this category are wind speed and direction, net radiation, and relative humidity. Wind speed, although useful in defining the baseline is most applicable to making correlations with potential evaporation, and therefore should be combined with the evaporation studies. Eliminating this parameter from the recording stations relates to another suggested modification: a more rigorous study of potential evaporation. Changing the methodology for these measurements for the use of Piche evaporimeters to an evaporation station at which wind speed and surface temperatures are measured is suggested. Another methodological change which is recommended for the monitoring period is the change from soil moisture measurements to making determinations of soil and plant water potentials. This information will provide a much more accurate view of plant/soil water relationships and moisture stress. In addition, the number of stations monitored might be deleted. Specifically, it is suggested that the number of microenvironmental spot check stations be reduced to include only those stations that monitor situations which are not redundant in terms of the continuous recording stations. Sites to be retained during the monitoring program would include those located in mixed mountain shrublands, bunchgrass communities, annual weed communities, Sorghum Gulch, and Cottonwood Gulch. Last, the equipment used in the continuous recording stations has been stressed by time and environmental severity of the Tract and is beginning to produce large data gaps and inaccuracies due to malfunction. It is suggested that these stations be revamped and automated to a cassette mode, thereby increasing the quantity and quality of data collected in a cost-effective manner.

The mircoenvironmental data base can be used effectively in the design of reclamation and revegetation plans, including design of seed bed treatments, species selection, planting and/or transplanting times, and follow-up treatments.

Microenvironmental data developed both during the baseline and the monitoring program can aid in reclamation efforts so that revegetation success is increased in such a way as to better provide habitat for those animal species potentially displaced during operational activities.

4.2 Soils

The soils on Tract C-b also comprise a major abiotic component of the ecosystem. Soils influence the composition and productivity of the vegetation and therefore can affect the distribution of animal species within the study area boundaries.

The soils data collected during the baseline studies provides information on which monitoring and reclamation programs can be built. Such information includes:

- The potential productivity of various soil types and thus their reclamation potential, their importance for browse and/or forage, the need to stockpile disturbed overburden and additional reclamation procedures.
- A data base for monitoring potential changes in soil chemical constituents to be used as a comparison against shale oil development activities, such as increased release of air pollutants or liquid effluents, which might alter the chemical make-up of soils. Sampling procedures used during the baseline period have produced a more than adequate data base. Additional monitoring phase sampling should be structured in such a way to obtain data on important parameters which relate to soil fertility. Other parameters, such as trace elements and physical features should be selected based on system interrelated factors such as known air pollutants and increased trace element sources.
- Information relative to the overall suitability of soil types occurring in areas which might be used to construct plant facilities, septic systems, housing, roadways, dam sites, and disposal areas.

Soil microorganisms are critical components in the biochemical transformation of organic material for use by higher plants, and perturbation which affect their abundance or function will ultimately affect the entire food chain. Therefore, monitoring their abundance will be useful throughout the duration of the project in order to detect potentially damaging impacts to soil organisms before higher plants and the remaining components of the food chain are affected.

The variability associated with data collected during baseline studies indicates that a larger number of replicates will be needed to sample adequately and discern potential effects of shale oil development from normal variability.

4.3 Vegetation

suggest Δ in productivity-util
measurements.

All of the data that have been collected as part of the baseline studies will be useful for making future comparisons. Some of the information which has been gathered will be useful for making statistical comparisons between baseline conditions and future values of system state variables such as herbaceous standing crop. Other observations will be useful for long-term trend analyses, since changes in parameters like tree radius increases occur at very slow rates.

4.3.1 Flora

The flora provides a listing of all vascular plants observed during the baseline period. Potentially, it will be used throughout the duration of the project in order to compare future observations with predevelopment information concerning the relative abundances of the species. Also, the only information for rare plant species is recorded in the abundance statements in the annotated flora. Continued recording of observed species should be a part of the on-going studies on the Tract.

4.3.2 Phytosociological Studies

4.3.2.1 Vegetation Mapping

The vegetation map of the Tract provides a blueprint for the distribution of the vegetation types within the study area. The information portrayed on the map will be useful in evaluating alternative development patterns such that impacts to important plant communities may be minimized.

4.3.2.2 Broadly Based Sampling Program

The data from this program provide information concerning dominant species in Tract plant communities. These data will be useful in assessing predevelopment structure and composition in these vegetation types. This information will serve as a performance standard against which future reclamation successes or failures may be measured. Additionally, the data will be useful in assessing construction impacts relative to the kinds and amounts of vegetation being adversely affected. If major changes in plant community structure and composition are noted elsewhere during the monitoring phases of the project -- particularly in successional areas such as the chained sites -- it may be desirable to resample the areas used to gather the baseline data using the same sampling methods. Otherwise, periodic resampling of these areas would not be required.

4.3.2.3 Intensive Study Plots

The intensive study plots serve as a nucleus for long-term monitoring since much of the baseline data were collected at these locations. The permanent quadrats and line transects located within the plots, and the permanently marked trees will allow for long-term comparisons of the same individuals and ground areas. Data from these sampling programs will be most useful in evaluating major plant community changes. Repeated sampling of the permanent plots using methods employed during the baseline should continue throughout the life of the project, since data from this program will allow for detection of major community changes. As the project progresses, it will be necessary to establish new permanent sampling locations in close proximity to point emission sources and also on reclaimed surfaces. These new locations will provide a better estimate of community changes than will the study plots located at greater distances from the disturbances.

4.3.3 Production Studies

Data from the production studies will be useful in evaluating the effects of development on the yearly growth of the plants. The baseline data are adequate and amenable to statistical comparison such that future changes may be evaluated in light of baseline conditions. Also, the estimates of standing crop will serve as a performance standard for evaluating revegetation programs. As site development progresses, it will be important to obtain yearly production estimates from both control sites and sites located adjacent to pollutant sources. Sampling should be accomplished twice per year at least until such a time that trends in herb production are clearly established.

The yearly production estimates form the basis for energy flow analyses relative to the amount of food available for large herbivore consumption. These data formed the basis for making evaluations of the relative importances of the various habitat types on Tract. Continued sampling will provide information on the continued use of these habitats during operation versus potential shifts in habitat uses.

4.3.4 Decomposition Studies

The decomposition studies provide information on one of the most important processes on the Tract. The data can be used in establishing turnover rates for nutrients and for estimating cycling time intervals. The studies also provide one of the few observations on soil microbial activity which may be very important in revegetation efforts. If changes in the vegetation are detected in the data from other monitoring programs, it would be desirable to repeat the decomposition studies at some time in the future. The same materials, sample sizes and locations should be used so that more direct comparisons could be made with the baseline data.

4.3.5 Herb Phenology Studies

The herb phenology studies provide information concerning the seasonal development of important herb species. These data document the percentage of the population that flowers and produces seed. As such, it provides insight into the natural reproduction of key species. Monitoring of herb phenology during the development phase of the project would be better accomplished using an approach different from that used during the baseline period. It would be more useful to keep yearly observational data on times of first apparent green-up, first flowering, full flowering, and senescence for a greater number of species. These observations could be made on a Tract-wide basis rather than being restricted to the intensive study plots.

4.3.6 Shrub Growth Studies

The shrub stem growth studies have provided a quantification of the responses of marked twigs to browsing by deer. These data may be useful when shrub plantings are considered for reclaimed surfaces. They also provide a record of twig growth rates during the baseline period. Because of the sampling problems associated with this study, it should not be included in the long-term monitoring of the Tract.

4.4 Animals

4.4.1 Big Game

4.4.1.1 Mule Deer Movement Patterns

Aerial observations of deer were conducted during baseline studies to obtain information on deer distributions throughout the winter in areas of difficult access. Although routine flights cannot be recommended for monitoring because of the lack of quantitative data generally obtained, occasional flights are highly recommended. If properly timed, this method provides a practical means of locating and documenting (photographically) deer concentrations during times of deep and prolonged snowpack. Such areas were not adequately described during baseline studies because of mild winters. Future studies need to be responsive to the possible effects of severe winter weather on all wildlife, and particularly on mule deer. The necessity of separating effects due to changing winter weather from effects due to oil shale development will be one of the more challenging problems of the deer monitoring program.

It is further recommended that a monitoring method be used to check for changing deer distributions, since it is reasonable to assume that disturbances from oil shale related activities will cause a behavioral displacement of deer. A local shift in deer distributions would not constitute a serious impact if deer numbers were not reduced as a consequence. Deer pellet-group transects located east and west of Tract C-b, as well as on the Tract, is one desirable means of detecting changing patterns of habitat usage.

Road counts are a convenient, practical way to monitor deer population trends, timing of migratory movements, adult-fawn ratios, and road kills. These data are fundamental to assessing the general status of the local segment of the Piceance deer herd and are considered valuable to a deer monitoring program.

4.4.1.2 Mule Deer Habitat Utilization

Baseline studies emphasized estimates of relative deer use in the major habitats within the C-b study area as well as the conditions of key browse species. Methods used were pellet-group counts and production/utilization studies. Both these studies are effective for monitoring changes in the local deer population and are of value to a deer monitoring program. It is recommended that sampling be continued on a twice yearly basis during the spring and fall. In addition, a change in methodology toward adopting some type of dimension analysis (twig to weight ratios) from twig measurements alone should be considered as a more cost effective approach.

4.4.1.3 Mule Deer Mortality Studies

Baseline studies emphasized describing the spatial pattern of deer mortality on the Tract study area. As such, important segments of the major habitat types were identified as areas of high mortality. This study should be considered complete, with there being no need of continuing it in the same manner as in the baseline studies. Two aspects of the study, however, have utility in terms of a long-term program. Namely, monitoring for disease (particularly florosis) and for significant yearly changes in the magnitude of winter kill. Both studies could be done concurrently, once each year, but would require field study sites in carefully selected locations.

4.4.2 Medium-sized Mammals

Baseline studies described habitat affinities and relative numbers of all medium-sized mammals. Long-term studies using methods applied during the baseline should continue to monitor population trends of cottontails because they are an important prey base for the larger mammalian and avian predators. Cottontails would also be an appropriate animal for detecting diseases related to introduced toxins.

4.4.3 Small Mammals

Parameters that were subject to a minimum of natural variability during the two year study, such as average live weight, will be most useful in future monitoring programs for detection of environmental perturbations of low magnitude or pollutants present at low levels. Other parameters, such as density estimates, were subject to annual and cyclic fluctuations of relatively large magnitude and may vary significantly from measurements during any two-year period. These more widely fluctuating parameters will be most useful in delineating long-term trends and may reflect subtle and chronic as well as gross environmental perturbations. Monitoring programs should be designed to account for natural fluctuations and allow statistical comparison of observed trends with baseline data.

The majority of parameters studied during baseline studies were assessed by a live trapping methodology. Therefore, the measurement of the more widely fluctuating parameters, which may not be justified in terms of man-hours expended or level of resolution if done separately, can be still accomplished during monitoring with a minimum of additional effort and cost since the data for all parameters may be collected simultaneously.

Specific parameters and their relative usefulness for inclusion in the monitoring program are listed below. Methods used during the baseline period will be effective in gathering comparative information during monitoring; however, sampling frequencies should be lessened.

4.4.3.1 Species Composition and Density Estimates

The monitoring of changes, in species composition and density estimates, which may occur between years or between control sites and impact areas, should be useful in assessing both future reclamation success and construction impacts relative to the modification of habitat structure. This evaluation is based upon the results of baseline studies which showed that both parameters appeared to be strongly associated with habitat structure. It is therefore suggested that these parameters be included in future monitoring programs although data collection can be continued on a reduced basis, i.e., biannually.

4.4.3.2 Home Range Size

Although alterations of home range size can be related to habitat quality, the number of captures required for this analysis is large and therefore would be prohibitive in terms of the effort expended.

4.4.3.3 Small Mammal Reproductive Condition

Although a correlation does not necessarily indicate cause and effect, there appeared to be a general relationship between the quality and quantity of green vegetation ingested and reproduction, especially in the females. These results suggest that there is an important biological interaction between the ingestion of green vegetation and reproduction, even though green vegetation is only one component of a variety of factors influencing reproduction. Reproductive condition may therefore be a good indicator of the relative condition of vegetation in control and impacted areas.

Other factors, such as stress due to noise or air pollutants, may also affect individual reproduction success before the effects become manifested at the population level.

Therefore, because of the potential for detection of several kinds of impacts, and because data relating to reproductive condition is easily and rapidly obtained during field studies and requires a minimum of effort to accomplish data reduction, this parameter is recommended for inclusion in the monitoring program.

4.4.3.4 Small Mammal Live Weights

Average live weights for similar age classes and the same sex were relatively consistent and did not vary significantly between years during baseline studies. For this reason, it is anticipated that impacts which affect live weights during shale oil development activities could be detected with a relatively high degree of precision without the confounding effects of natural variability.

Body weights are known to be affected by a number of factors such as trapping stress, low level radiation, weather, habitat quality (e.g., food resources), and population exploitation (i.e., predator or disease induced). For this reason, although a change in average live weight may be a relatively sensitive indicator of environmental stress, additional studies would subsequently need to be initiated to delineate specific causal agents.

As discussed for reproductive condition, monitoring live weights may allow the detection of environmental stress before the effects become apparent at the population level, i.e., significant alterations of density and species composition.

4.4.3.5 Small Mammal Survivorship and Turnover Rates

This parameter is similar to average live weight data in that it may be affected by a wide range of factors and may be useful in assessing the effects of environmental stress before they become apparent at the population level as evidenced by population declines. The sensitivity of this parameter to environmental stress may be so great that small declines in survivorship can be observed that do not affect the ability of populations to maintain their numbers at normal or baseline levels.

Although this parameter appears to be a relatively desirable parameter to monitor, in terms of sensitivity and precision, survivorship is difficult to assess since mark and recapture techniques are required on a frequent basis, i.e., monthly trapping efforts over a 6-8 month period. Since the determination of average live weights requires much less effort than determination of mean survivorship and because live weights appear to be equally sensitive to a wide range of environmental stresses, it is suggested that the average live weights should be monitored rather than monitoring for survivorship in order to achieve the best cost-benefit ratio.

4.4.3.6 Small Mammal Food Habit Studies

Species observed during baseline studies, appeared to be opportunistic in their feeding, subsisting on a variety of foods and utilizing different kinds as they became available. Therefore, it is anticipated that impacts on specific food items would result in rodents selecting new food sources not affected by a given impact. The analysis of such a change in diet would involve identification of specific food items, to genus and species, and the determination of the relative caloric and nutritional value of alternate food sources. These programs would require considerable effort and expenditures. Since significant impacts to rodent diets should ultimately be reflected by other parameters such as average live weights and considering the effort required for monitoring of this parameter, it is suggested that the program is not implemented in future monitoring plans.

4.4.4 Birds

The value of the data collected on birds during the baseline study is principally three-fold. First, they serve as input to engineering design and construction scheduling. Second, they serve as the basis for comparisons with future data collected during the long-term monitoring program, to ascertain if changes occur in distribution and density of species presently living in

Tract areas which will be modified or otherwise affected by construction activities and operational emissions. Third, they serve as a basis for refining the long-term monitoring program, so only those state variables that are most assessable to measurement will be included in the monitoring program.

Examples of input to engineering design and schedule result from what was learned during baseline investigations of the importance of certain habitat types for birds. For instance, the riparian habitat along creeks close to the Tract have special importance to many species including waterfowl, greater sandhill cranes, mourning doves, and many songbirds throughout the year or during special seasons. Consequently, measures should be taken to avoid habitat destruction or disruption in these areas. The rimrock habitat overlooking the valley slopes forms especially important nesting habitat to many raptor species. Construction activities should be scheduled to minimize noise and physical disturbance in these areas during the major period of raptor nesting.

As explained in the Appendix IV-A section on general data efficacy, the data having most general utility for present characterization of avian community composition and dynamics and for comparing to future conditions, are those obtained during the breeding period. This results because bird community species composition and abundance tend to be most stable during the nesting season; therefore, accurate census data are most easily obtained during the late spring and early summer, when males are spatially fixed to their territories and are highly visible and vocal. As a consequence, data on breeding avifaunas from the two years of baseline investigations will be the most useful for comparing to future data obtained during the development and operational phases of oil shale production on the Tract. Considerable information is at hand on what constitutes the principal breeding species in each of the major habitat types; moreover, baseline data on densities and relative abundances of these species will be useful for demonstrating whether development and processing activities are responsible for substantive changes in avian communities close to construction activities or within zones of concentrated emissions. The experimental design for the development and operation phase monitoring programs takes fullest advantage of using baseline data on breeding birds as a basis for such determinations. Moreover, the experimental design takes into consideration what was learned in the baseline program about kinds of data that are not too useful for short-term and long-term trend comparisons.

4.4.5 Reptiles and Amphibians

Due to their relatively low abundance and difficulties associated with mark and recapture techniques this group is not considered as potentially useful for inclusion in any monitoring programs implemented.

4.4.6 Arthropods

4.4.6.1 Shrub Dwelling Arthropods

During baseline studies, it was observed that the species composition of shrub dwelling arthropods was determined primarily by the shrub species sampled and that relative abundance was determined by the general condition or phenology of those shrub species.

It is recommended this program be continued on a system dependent basis during the monitoring program because these two parameters will be useful in judging future reclamation success and in assessing construction and operation impacts on the vegetation affected.

4.4.6.2 Ground Dwelling Arthropods

The majority of species collected from pit cans were classified as omnivores or carnivores and were consequently not dependent on specific plant species for survival. As a result, this group would be less susceptible to removal of vegetation and the effects of air pollutants on plant physiology than are herbivorous shrub dwelling arthropods, as well as other detrimental effects of oil shale development. For this reason, monitoring of ground dwelling arthropod abundance and distribution may not be particularly valuable in assessing the effects of oil shale development and it is therefore recommended that this program should not be included in the monitoring program.

4.5 Aquatics

Data from the aquatic studies conducted during the baseline program will be useful in detecting changes due to the development and operation phases. They allow selection of the most useful monitoring methods for detection of environmentally induced changes resulting from mine operations.

4.5.1 Water Quality

The physical and chemical parameters measured during baseline studies will also be useful to detect degradation of water quality in the streams surrounding the Tract. Those parameters most likely to be altered by mining operations should be the factors selected for analysis during monitoring. Total dissolved solids, suspended solids, pH, and some of the elements present in ground waters in high concentrations, will be useful in analyzing the effect of drilling and dewatering on the stream communities. Erosion could create increased siltation in streams; therefore, data on turbidity, siltation levels, and grain size analyses will be useful for analyzing effects of development-related erosion on streams and aquatic species.

4.5.2 Periphyton

Periphyton species are frequently the major primary producers in streams. Since they are attached to the substrate, and incapable of migration, they respond to changes at a given site. Their relatively short life cycles result in fairly rapid population responses to changes in the environment. Periphyton productivity data will be useful during monitoring for comparisons of any changes in the quality of the aquatic system. Species composition can be used to detect elimination of species unable to tolerate degraded conditions, and biomass will indicate if stream production has been altered. Monitoring of periphyton should continue with sampling frequency determined by varying environmental and operational influences.

4.5.3 Benthos

Quantitative data collected on benthic communities will be useful in detecting changes in the aquatic invertebrate communities. Biomass, species diversity, and quantitative abundance can be used during monitoring to detect degradation of the benthic species. The occurrence of more "polluted water species" or disappearance of "clean water species" can also be utilized in detecting degradation of the stream environment. Sampling of benthos for species identification, biomass measurements, species diversity, and quantitative abundance should continue. Benthos population levels are highly cyclical since the majority of benthic organisms are insect larvae which periodically mature and leave the water. These cycles have been established during the baseline and further sampling should be directed toward different environmental conditions (extreme high flow, low flow, possible continued turbidity from construction, increased levels of trace elements, etc.). Benthic organisms are the lowest animals in the aquatic food chain and therefore are early indicators of degradation in water quality. These organisms are sediment dwellers where some elements tend to accumulate and concentrations of such elements may differ from the surrounding water.

4.5.4 Fish

Changes in fish populations can be detected by examination of numerous factors which affect the overall functioning of the population. Many of these were measured during the baseline studies. Changes in the environment do not affect all age classes the same. Reduced production will show up in younger age classes, etc. Distribution, abundance, spawning activity, fecundity, and the ageing of individuals should be continued as monitoring parameters for fish populations, but at a much reduced sampling frequency. Fish being at the top of the aquatic food chain (disregarding birds and man) will show the effects of gradual pollution much slower than periphyton and benthos. Also there are much fewer species of fish than periphyton and benthos and the more diverse the species the better chance there is of having a sensitive indicator species. For these reasons it is necessary to sample fish only when significant changes are noticed in periphyton and benthos diversity and biomass are alterations in water quality that were not tested for during baseline and interim monitoring. These parameters can be used to assess the streams' continued ability to support fish populations and provide adequate habitat for spawning, feeding, etc. Population estimates can also be useful in this regard.

4.5.5 Springs and Seeps

Inventories of springs and seeps will be useful in detecting any changes in ground water conditions and aquifers due to dewatering or mining operations, and disappearance of existing springs or seeps due to development activity.

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APPENDIX A

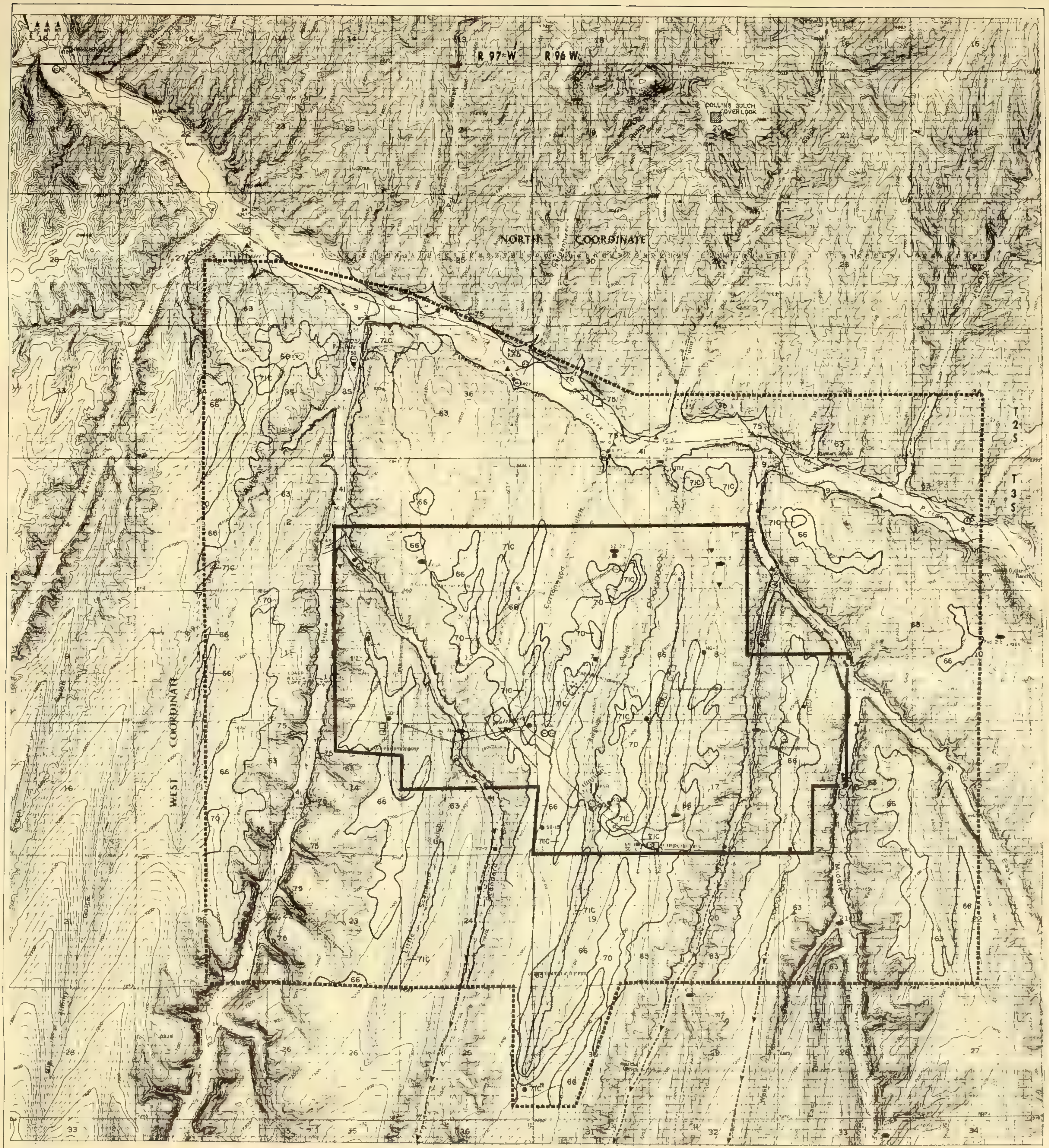
METHODOLOGY, EXPERIMENTAL DESIGN, AND QUALITY ASSURANCE

(Refer to the supplementary Volume IV,
Ecology, Appendices A and B which
accompanies this Volume)

APPENDIX B

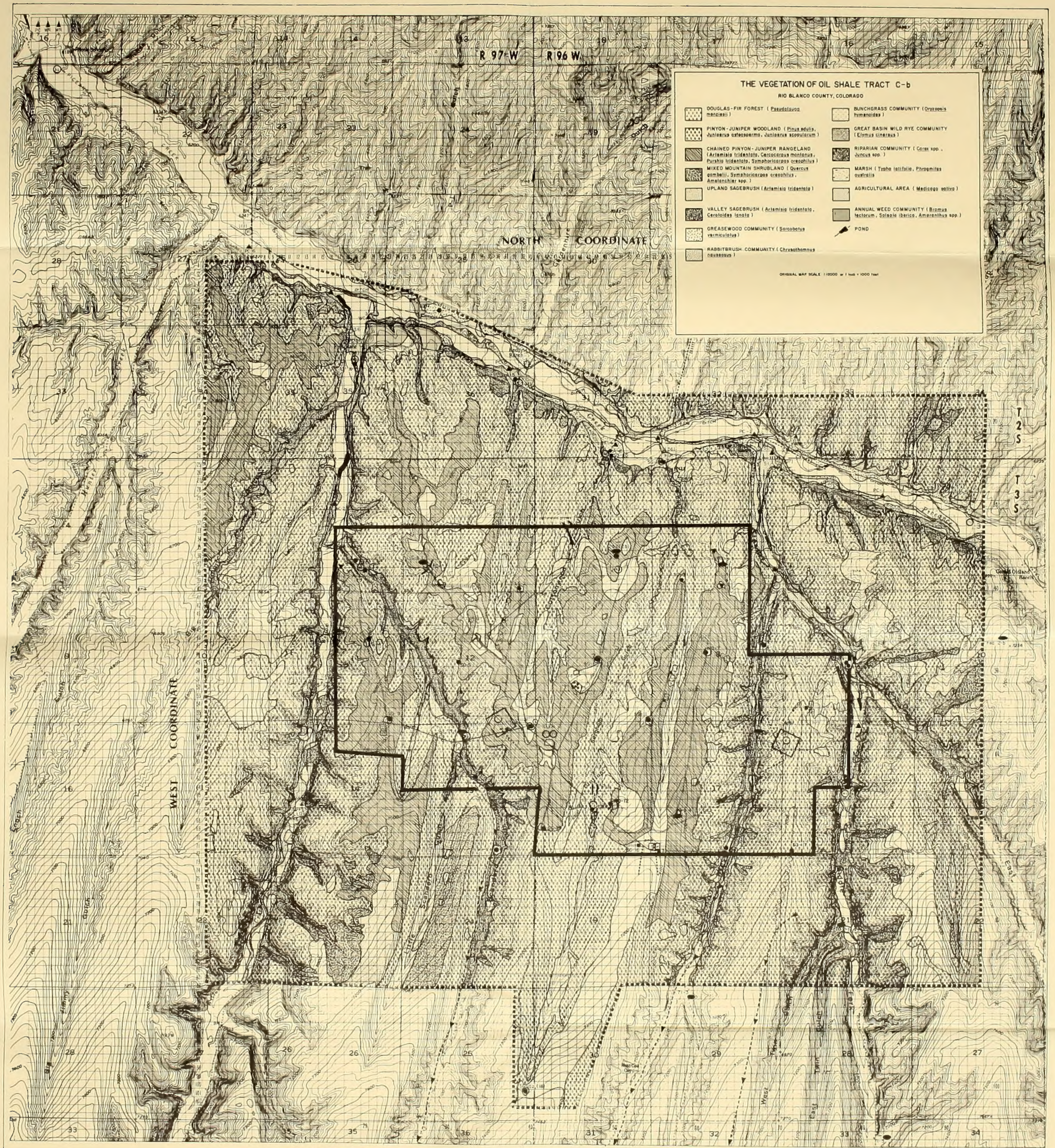
DATA PRESENTATION

(Refer to the supplementary Volume IV, Ecology, Appendices A and B which accompanies this Volume)



9 • HAGGA LOAM
41 • GLENDIVE LOAM
63 • RENTSAC-CHANNERY
66 • REDCREEK-RENTSAC COMPLEX
70 • PICEANCE LOAM
71C • FORELLE LOAM
75 • RIVRA LOAM

SOILS MAP
POCKET FIGURE 3-2-1


THE VEGETATION OF OIL SHALE TRACT C-b
RIO BLANCO COUNTY, COLORADO
DOUGLAS-FIR FOREST (Pseudotsuga menziesii)
PINYON-JUNIPER WOODLAND (Pinus edulis, Juniperus osteosperma, Juniperus scopulorum)
CHAINED PINYON-JUNIPER RANGELAND (Artemisia tridentata, Cercocarpus montanus, Purshia tridentata, Symphoricarpos oreophilus)
MIXED MOUNTAIN SHRUBLAND (Quercus gambelii, Symphoricarpos oreophilus, Amelanchier spp.)
UPLAND SAGEBRUSH (Artemisia tridentata)
VALLEY SAGEBRUSH (Artemisia tridentata, Ceratoides lanata)
GREASEWOOD COMMUNITY (Sarcobatus vermiculatus)
RABBITBRUSH COMMUNITY (Chrysothamnus nauseosus)
BUNCHGRASS COMMUNITY (Oryzopsis hymenoides)
GREAT BASIN WILD RYE COMMUNITY (Elymus cinereus)
RIPARIAN COMMUNITY (Carex spp., Juncus spp.)
MARSH (Typha latifolia, Phragmites australis
AGRICULTURAL AREA (Medicago sativa)
ANNUAL WEED COMMUNITY (Bromus tectorum, Salsola iberica, Amaranthus spp.)
POND
ORIGINAL MAP SCALE 1:12000 or 1 inch = 1000 feet
R 97 W
R 96 W
NORTH COORDINATE
WEST COORDINATE
T 2 S
T 3 S

LEGEND

WATER GAUGING STATION
AIR QUALITY METEOROLOGICAL
SUPPORT FACILITIES
▲ AQUATIC SAMPLING SITE
PC-PICEANCE CREEK
WC-WILLOW CREEK
SC-STEWART CREEK
POWER LINE
S3 ○ SPRING OR SEEP
SG-12 ● PROPOSED CORE HOLE LOCATION
● A-13 PROPOSED ALLUVIAL CORE HOLE LOCATION

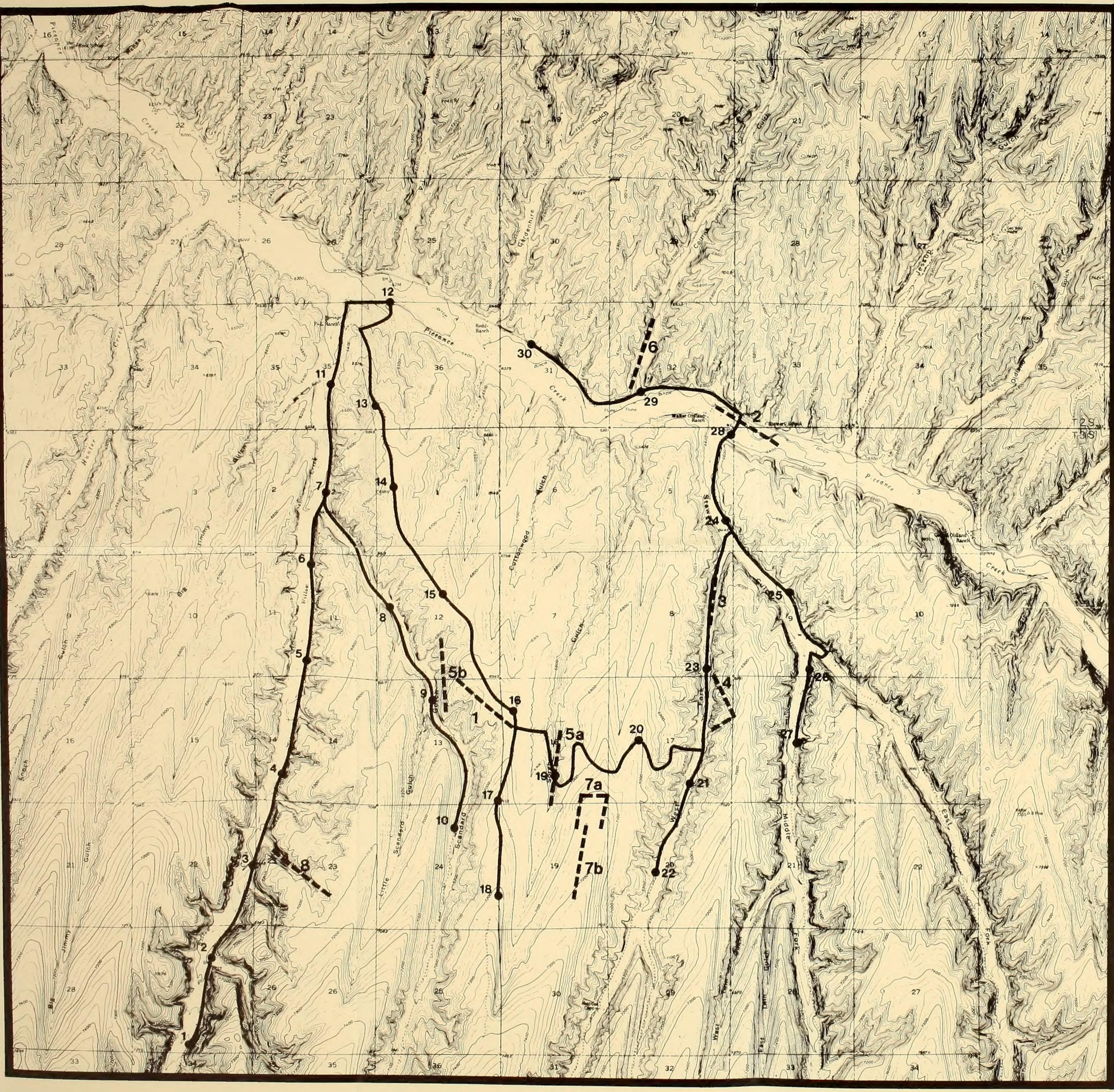
● NQ-7 PROPOSED SLANT CORE HOLE LOCATION
VO VF VEGETATION SITE: VO = OPEN (50 X 70 m) VF = FENCED (50 X 70 m)
SITE NO -
1. CHAINED PINYON, JUNIPER (EXPERIMENTAL)
2. CHAINED PINYON, JUNIPER (CONTROL)
3. PLATEAU SAGEBRUSH
4. VALLEY SAGEBRUSH
5. PINYON, JUNIPER (EXPERIMENTAL)
6. PINYON, JUNIPER (CONTROL)
■ MICROENVIRONMENTAL STATIONS

Ⓐ ANIMAL TRAP SITE (800 X 800 ft)
SATELLITE ANIMAL TRAP TRANSECTS
DEER PELLET AND BROWSE UTILIZATION TRANSECTS
ORNITHOLOGICAL STUDY TRANSECTS
✳ WATERFOWL SYSTEMATIC OBSERVATION SITES
PSA & PSB PARASITE SAMPLING SITE
○-○-○-○ ANIMAL TRACK COUNT TRANSECTS
PREDATOR SCENT-POST SURVEY LINES
● PRELEASE CORE HOLE LOCATION
▼ OTHER SENSITIVE AREAS

POCKET FIGURE 3-3-2

POCKET FIGURE 3-4-13

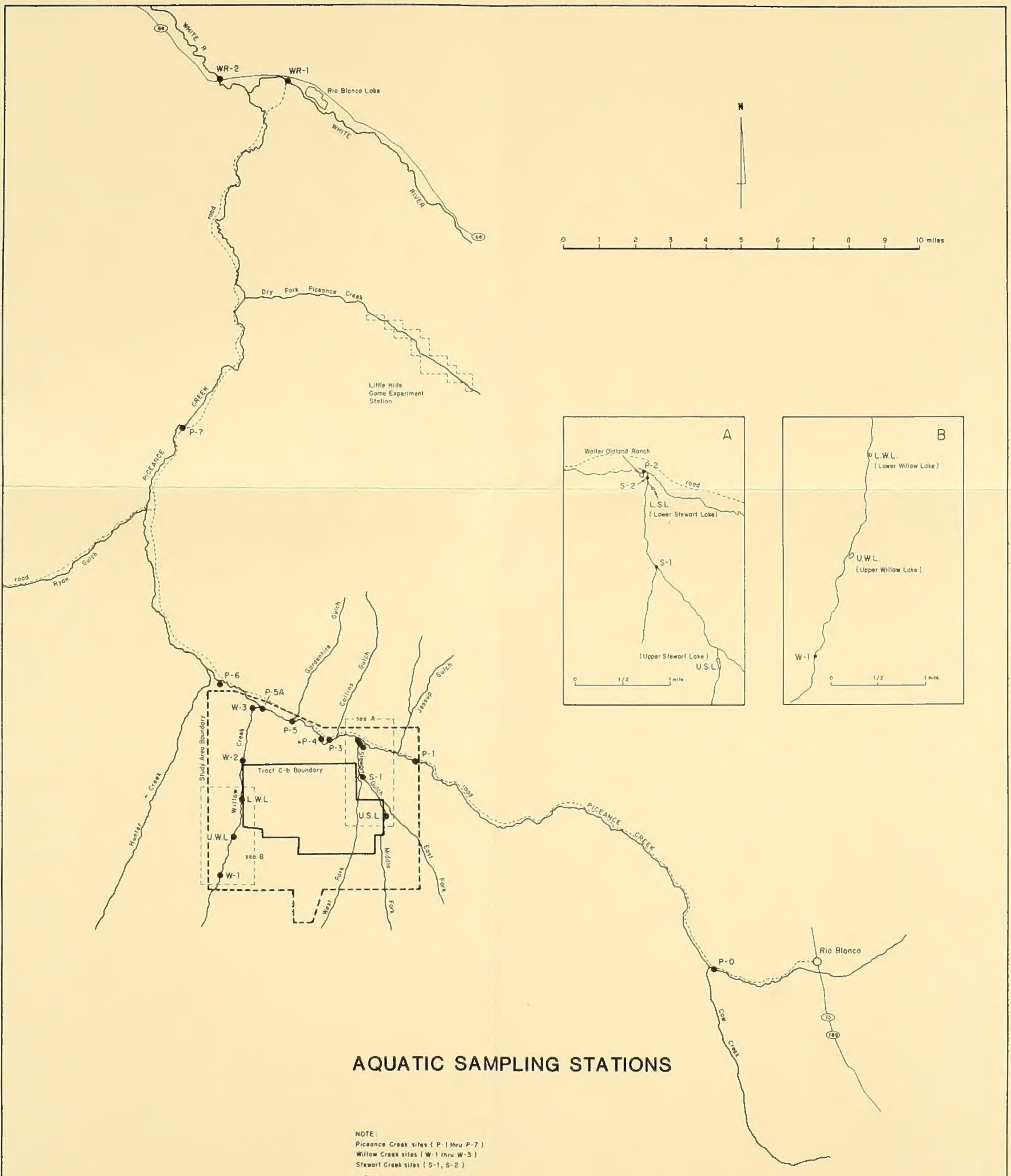
LOCATION OF BIRD STRIP TRANSECT LOCATIONS AND NIGHT OWL SURVEY ROUTE ON TRACT C-b AND ENVIRONS



– – – – AVIFAUNA STRIP TRANSECT LOCATIONS

—— NIGHT OWL SURVEY ROUTE

● STOP POINTS ON NIGHT OWL SURVEY ROUTE



AQUATIC SAMPLING STATIONS

NOTE:
Piceance Creek sites (P-1 thru P-7)
Willow Creek sites (W-1 thru W-3)
Stewart Creek sites (S-1, S-2)

* P-4 has been relocated to P-5A.

POCKET FIGURE 3-5-1